THE AMERICAN ENCYCLOPEDIA AND DICTIONARY OF OPHTHALMOLOGY

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Volume IV — Cocaine to Conjunctivitis Phlyctenulosa Miliaris

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LIST OF LEADING SUBJECTS IN THIS VOLUME

Cocaine. Erythroxyline. Methyl-benzoyl-ecgonine. This agent, so extremely important from the standpoint of the ophthalmic surgeon, is derived from the leaves of erythroxylum coca, with the formula $C_{17}H_{21}NO_4$. It is the best known and one of the most useful local anesthetics we possess. This alkaloid is present in coca to the extent of about one-half of one per cent. and occurs in the shape of colorless prisms, soluble in 600 parts of water, five of alcohol, twelve of olive oil; insoluble in lard and vaselin. The hydrochloride is its best known salt, although the benzoate, borate, citrate, hydrobromide, hydriodide, lactate, nitrate, tartrate, salicylate, phenate, oleate, stearate (best for ointments), and sulphate are well known. The *National Formulary* recommends cocaine borate instead of the hydrochloride in solutions intended for ocular use on account of its greater stability.

The most frequently used incompatibilities with cocaine and its salts are its combination in solution with zinc sulphate and sodium borate, both of which precipitate it.

As the hydrochloride is incompatible with silver salts cocaine nitrate should be used in lieu of the hydrochloride when argentic compounds are prescribed with it.

In the usual dosage, 3 to 5 per cent., it dilates the pupil moderately, is a feeble cycloplegic, produces anemia of the conjunctiva and is a dangerous poison. The drug greatly increases the action of other alkaloids with which it is instilled into the conjunctival sac, probably because its desiccating and loosening action on the anterior corneal epithelium enables the solution to reach more easily the substantia propria. The eyes should always be kept closed during the first stages of cocain instillation as this largely neutralizes the hurtful action of the drug on the cornea. Michel goes even further than this in claiming that the exfoliation of the pavement epithelium may be so marked as to justify calling the condition cocain keratitis and advises one to cover the eye with a moist compress when strong solutions are used or the drug applied for any length of time. It is claimed that this agent may precipitate an attack of glaucoma, while even from simple instillations into the eye of a comparatively weak solution toxic symptoms (vertigo, pallor of the face, fainting, thick speech, weak pulse, loss of consciousness, etc.), may occasionally show themselves, requiring alcoholics, amyl nitrite inhalations and other stimulation for their relief.

Although numerous local anesthetics, especially eucain (q. v.) and holocain (q. v.), have been advised as substitutes for cocain it is still the favorite agent in operative procedures. The Editor prefers (as giving the maximum anesthesia with the least cocain) for the average

ophthalmic operation the following formula: Cocain. hydrochlor. gr. xx; Holocain. hydrochlor. gr. v; Aquæ dest. et steril. ℥j. Instil one drop every three minutes for 12 minutes.

Although several observers believe that the anesthetic action of solutions of cocain, both of the alkaloid and of the salts, is lessened or destroyed by boiling, this view is not held by C. R. Holmes who always sterilizes his solutions in this way, and has used it for operations upon the eye, ear and nose thousands of times. In his experience it is the rarest thing to find that the drug is not efficacious, and in these rare cases he has attributed its lack of action to the idiosyncrasy of the patient.

Wintersteiner (Merck's *Annual Reports,* 1906, p. 91.) reported in 1906 that in spite of alleged substitutes, cocaine is still the sovereign local anesthetic for eye work. Sommer (*Wochenschr. f. Therapie u. Hyg. des Auges,* 1907, No. 51, p. 402.) has also had considerable experience of the so-called substitutes for cocaine, has given them all a thorough test and believes them to be inferior to cocaine. Without ignoring the toxicity of cocaine, the substances which have been suggested in its stead are, he thinks, all more or less make-shifts, and not substitutes.

Cocaine is of good service in the intra-muscular injection of mercury salts, to diminish or abolish pain. Since the simultaneous use of cocaine and mercury salts leads to the formation of sparingly soluble double combinations, P. Salmon (*Semaine Médicale,* 1907, No. 3, p. 34) advises that the injections be made at different points, injecting the cocaine solution more deeply, the mercurials superficially. In this way it is possible to inject large quantities of the mercury solution without pain, and so reduce the total number of injections. The dose recommended by the author is 1 c. c. (m. 16) of a 1 per cent. solution of cocaine.

Theobald (*Jour. Amer. Med. Assoc.,* July 27, 1907) finds adrenalin useful not only to check hemorrhage, but he believes it increases the anesthetic action and reduces the toxicity of cocain. It is valuable in operations on the ocular muscles, the lachrymal passages and on chalazia and other tarsal cysts. In cataract extraction it may cause collapse or opacity of the cornea. In iridectomy it aids materially. In pterygium, it is contraindicated, as excessive blanching obscures this condition. In ocular traumatism hemorrhage is checked, and the detection and removal of foreign bodies imbedded in the superficial structures of the eye is aided. Adrenalin may be sterilized by boiling for a short time without impairing its efficiency. See, **Anesthetics, Local.**

Cocain hydroiodate. $C_{17}H_{21}NO_4$. HI. This salt appears as colorless crystals only slightly soluble in water. It has been suggested as a substitute for cocain hydrochlorate in producing cataphoresis (q. v.).

Cocain-morphin. This is a mixture, suggested by Eversbusch, of cocain salicylate and morphia hydrochlorate, employed as a local anesthetic in iridectomy, sclerotomy, etc., as well as a palliative remedy in blepharospasm.—(*Encyklopädie der Augenheilkunde.*)

Cocain phthalate. A syrupy liquid soluble in water. It contains 64.6 per cent of the alkaloid. It has been employed hypodermically as a substitute for cocain hydrochlorate.

Cocain saccharate. This compound appears as moist crystalline plates mostly used in diseases of the throat. A 5 per cent. solution corresponds to a 4 per cent. solution of cocain hydrochlorate.

Cocain stearate. $C_{17}H_{21}NO_4C_{17}H_{35}COOH$. A cocain compound appearing as brilliant clusters of needles, melting at about 90° C. It is quite soluble in alcohol and ether, slightly so in chloroform, benzin and oil of turpentine.

Cocain tartrate. $(C_{17}H_{21}NO_4)_2C_4H_6O_6$. A salt of cocain appearing as a white powder soluble in water. It is prescribed for the same purposes and in the same dosage as cocain hydrochlorate.

Cocaintrübung. (G.) Corneal opacity from cocaine.

Cocapyrin. This is a mixture of cocain, 1 part; antipyrin, 100 parts. It is used as an analgesic and antipyretic. Dose, 3½ gr. (0.22 gm).

Cocarenaline. See **Adrenaline.**

Coccidæ. Sakaguci (*Nippon Gankakai Zachi,* March, 1911) records a case in which some member of the family of the *Coccidæ,* or scale-insects (living on plants), had entered the sac and set up a conjunctivitis.

Coccius, Ernst Adolf. Born Sept. 19, 1825, in Knauthain, near Leipsic, Germany, he studied at the Universities of Leipsic, Prague and Paris. The chief among his teachers of ophthalmology was Ritterich. After his return from Paris to Leipsic he served for some years as assistant and privat-docent. In 1857 he was made extraordinary, and in 1867 ordinary, professor of ophthalmology—all at the same university.

He was one of the earliest workers with the ophthalmoscope, and, in fact, was the first to make an important modification of the instrument as invented by von Helmholtz. He was also the first to describe the reflex of the *fovea centralis,* as well as a number of other ophthalmoscopic phenomena. He was also the first to describe the filtration scar in glaucoma, as well as newly-formed blood-vessels in the vitreous. He it was who first pointed out that the retina could be ren-

dered visible by laying against the cornea a glass slide on which had been placed a drop of water. He discovered detachment of the retina.

In addition to all these things, he made important contributions to ocular tonometry, the examination of the fundus with polarized light, to our knowledge of variolous ocular inflammation and of the visual purple, and, indeed, to a number of other important ophthalmologic matters.

His chief writings are: *"On the Nutrition of the Cornea," "On the Employment of the Ophthalmoscope, together with the Description of a New Instrument," "On Glaucoma, Inflammation and the Autopsy with the Ophthalmoscope," "On the Structure and Inflammation of the Vitreous Body," "The Mechanism of Accommodation in the Human Eye," "Ophthalmometry and Tonometry," "On the Diagnosis of the Visual Purple during Life."*—(T. H. S.)

Coccius's ophthalmoscope. This is one of the earlier forms of the instrument, and is described and pictured by Soelberg Wells (*Diseases of the Eye*, p. 319), as follows:—Coccius's ophthalmoscope (see figure), as made at present, consists of a plane metal mirror, having a small central aperture. Behind the mirror is a hinged clip to hold a convex or concave lens. A lateral bi-convex lens of 5 to 7 inches focal length is held in a large clip mounted on a jointed bracket, which is so connected with the neck of the handle that it permits of the lens being moved to either side of the mirror. The original form of Coccius's ophthalmoscope (see figure) differed from that which I have described above, and which is at present in general use, both in being square in shape, and in being made of glass instead of metal. The square mirror was inconvenient, and could not be steadied so well against the orbit as the circular. But the great disadvantage of the glass mirror was (as Helmholtz pointed out) that the aperture could not be beveled down to so fine an edge as the metal one, in consequence of which more or less of a canal existed, which intercepted many of the peripheral rays, and produced considerable diffraction. The mode of using Coccius's ophthalmoscope is as follows: The collecting lens is to be turned towards the flame, which should be somewhat more than twice the distance of the focal length of the lens from the observer. The mirror is then to be set somewhat slanting to the lens and the eye of the patient. If the mirror is properly adjusted for the lens and the flame, we shall obtain, if we throw the image of the flame upon the palm of our hand or the cheek of the patient, a bright circle of light, with a small dark central spot, which corresponds to the opening in the speculum. The dark spot is then to be thrown into the pupil of the eye under examination, the surgeon placing the mirror close to his own eye, and looking through

the aperture into the patient's eye, which should afford a bright luminous reflex. For the indirect mode of examination a bi-convex lens of from 2 to 3 inches focus is to be held before the eye under observation. He, moreover, also uses a convex lens of 8 or 10 inches focus behind the mirror, in order still more to magnify the image. If the direct examination is employed, a concave lens will generally be required behind the speculum. At first this instrument may be somewhat more difficult to use than the concave mirror, on account

The Original and Improved Forms of Coccius's Ophthalmoscope.

of our having to regulate the position of the collecting lens with respect to the flame and the mirror; but a little practice and perseverance will very soon overcome this difficulty.

Coccius's orthoscope. This is one of several instruments devised to take advantage of the fact that when the eye is immersed in water the refraction of the cornea is neutralized. The device of Coccius is described and pictured in Norris and Oliver's *System* 2, p. 71. It took the shape of a cup, the rim of which was made to fit tightly around the eye and the bottom of which was made of glass; this small vessel,

filled with water, could be held to the eye close enough to permit an examination of the fundus without other help. See, also, p. 591, Vol. 1, of this *Encyclopedia,* as well as under **Hydrophthalmoscope.**

The Orthoscope of Coccius.

Coccoglia. (L.) A mass of micrococci held together by a glue-like substance formed during the process of segmentation.

Coccothrix. (L.) In the morphology of the *Schizomycetes,* a rod-form composed of a row of cocci joined by a cement substance of different composition.

Cocculus peltatus. (L.) The *Cyclea peltata,* a plant indigenous to the East Indies and Ceylon. An infusion of the leaves and root is used in the East in ophthalmic inflammation.

Coccus flavus desidens. (L.) This is a name given to the bacterial contents of a phlyctenule developed in the cornea of a rabbit, and found to be associated with keratitis and well-marked pericorneal injection. As a result of this and similar experiments it was thought that it might be a cause of phlyctenular disease in man.

Cochlear. (L.), n.n. A spoon; among various medical authorities a measure varying from ½ a fluidrachm to ½ a fluid ounce.

Cochleares. (It.) Curette.

Cochon. (F.) Pig; hog.

Cockatrice. The modern name for the ancient basilisk, a fabulous animal supposed to possess the power of killing by a look. See **Basilisk.**—(T. H. S.)

Cock-eye. Strabismus, or squint.

Cockroach, The. Blatta orientalis. Although oily matter, blattaric acid, antihydropin (taracanin), etc., are obtained from the cockroach, yet it has little to do with ophthalmology except that occasional mention is made of the insect's bites on the lids. *Blatta orientalis* is said also to yield small quantities of *cantharidin* which may account for the itching, swelling and other irritant signs set up by injury from the animal. The Editor has seen the lids and eyeballs of a number of young kittens severely bitten and almost destroyed by these carnivorous insects.

Cock's comb. *Rhinanthus crista galli.* In ancient Greco-Roman times a grain of Cock's comb seed was placed between the eyelid and the

eye for various ophthalmic affections. If the grain swelled, it was supposed to be drawing out from the afflicted organ the *materies morbi;* otherwise, not. A decoction of the seed produced by boiling it with honey and coarsely ground beans, was used in the vague affection known as "weakness of the sight."—(T. H. S.)

Cocles. (L.) adj. Having one eye.

Cocos schizophylla. (L.) A plant whose fruit is used in "ophthalmia."

Cocotier schizophylle. (F.) See **Cocos schizophylla.**

Cocotte. (F.) Edema of the eyelids.

Coda dell'occhio. (It.) Canthus.

Codalian. (Welsh.) The *Atropa belladonna.*

Coddington lens. A lens formed from a sphere of glass by cutting a deep, V-shaped equatorial groove around it, and filling the groove with some opaque substance. Also, the name given to the ordinary lens used for considerable magnification of the anterior ocular tissues, especially of the cornea.

Codein, ocular symptoms of. Although this remedy is commonly used in general pratice, it gives rise to few genuine ocular symptoms. Medvei (*Internat. Klin. Rundschau,* 1892, p. 1457 mentions that after a ½ grain dose of codein a marked congestion of the bulbar conjunctiva was noticed, and there was dilatation of the pupil. On the other hand, bilateral miosis and horizontal nystagmus have been recorded by others.

Codethyline hydrochloride. See **Dionia.**

Cod liver oil. Oleum jecoris aselli. Oleum morrhuæ. This agent is a fixed oil obtained from the fresh livers of Gadus morrhua and other fish. The purest oil is of a pale-yellow color, with a bland, fishy taste and smell.

Aside from its internal administration attention is drawn to this oil as an excipient for and diluent of ointments. The Editor has found it of great value in the preparation of "brown" ointment q. v.) a stimulant mixture of considerable utility in massage.

Codrenin. See **Conephrin.**

Codwarth. (Welsh.) The *Atropa belladonna.*

Cœloma. (F.) Deep ulcer of the cornea.

Cœlophthalmia. (L.) Obsolete. Hollowness of the eyes.

Cœlophthalmus. (L.) adj. Hollow-eyed.

Cœnadelphe. (F.) Double monster having two bodies nearly equally developed.

Cœur. (F.) Heart.

Coffee, Amblyopia from. As suggested by the Editor (*The Toxic Amblyopias,* 1892) many years ago, this stimulant, when taken in large

and continued doses, is capable of producing various eye symptoms—especially weakness of accommodation, temporary amblyopia, transient red and green blindness and metamorphopsia. The local action of a strong solution of coffee has been discussed by Robertson (*Brit. Med. Journ.*, Jan. 3, 1885, p. 17). The case that he described suffered from a burning sensation followed by a mild conjunctivitis and mydriasis. Others have observed anesthesia of the cornea from the same cause. Jonathan Hutchinson is also said to have observed a genuine case of coffee amblyopia.

Widmark (*Mitt. a. d. Car. Med. Ch. Augenklinik,* Part IX, 1908) records two cases of toxic amblyopia where the disease was due to the *excessive use* of coffee. The first case was that of a married woman, 32 years of age, who complained that her sight had been failing for five months. She was very thin and her face was of an ashen-gray tint. There was neither sugar nor albumin in the urine. An examination of her eyes showed slight pallor of the outer part of the discs, visual fields of full extent or only very slightly contracted peripherally, and well-marked central scotomata for red with a small spot of absolute scotomata in each. The patient denied ever taking either alcohol or tobacco, but admitted that she drank a great deal of coffee, in fact almost "lived on coffee." Widmark thought it hardly likely that this could be the cause, and put her on iodide of potash, under which she showed in three weeks some improvement in her vision. On her discharge from the hospital she returned to her old habits. Her sight and general health became so bad that she went to reside near the sea and there lived principally on a milk and fish diet, drinking only two cups of coffee daily. With this change the patient improved again and on the last examination her sight was much better. She could read Jaeger 1, and the scotoma for red had disappeared.

From this case Widmark was inclined to class excessive coffee-drinking with carbon bisulphide, iodoform, etc., among the rarer causes of this form of amblyopia, especially since two cases of this kind, due to the immoderate drinking of tea, have been recorded; and his suspicions were fortified by a second case which came under his observation. This was a woman of 45 who gave a history of long-continued weakness, loss of appetite, frequently recurring severe pain in the region of the stomach, periodic pain in her left eye with hemicrania, and for some weeks loss of sight. On examination it was found that the retinal veins were slightly congested, and the fundus presented a reflex slightly greyer than the usual bright-red appearance; the fields were normal at the periphery, while at the center

there was a scotoma for red, slight in the one eye, well-marked and of typical form in the other. To an inquiry about the use of alcohol the patient gave an emphatic denial; she had on a very few occasions tried smoking to alleviate her attacks of gastric pain. On the other hand she admitted drinking coffee to quite immoderate degree. For the purposes of control she was taken into the hospital and put on a mixture containing nux vomica and a bitter infusion, coffee being entirely forbidden. She made a speedy recovery; in ten days her sight had practically returned to normal, and the scotoma was no longer detectable.

Little, if anything, can be found in the more recent literature regarding the effect of excessive coffee-drinking on the eye. Widmark cites two cases recorded by Bulson (*American Journ. of Ophthalmology,* 1905) but, judging from the notes that are given of them, he criticises them as not true cases of toxic amblyopia.

Coffinism. A form of medical practice founded upon the dicta that "heat is life," and that "the want of heat is disease and death." It seems to resemble Thomsonianism. Lobelia and capsicum are said to be the only medicines employed. It takes its name from one Dr. Coffin.

Coffinite. An adherent or practitioner of Coffinism.

Coggin, David. An American ophthalmologist and otologist, especially renowned as the first to suggest the use of the binaural stethoscope as a means of detecting feigned unilateral deafness. He was born at West Hampton, Mass., Aug. 4, 1843, the son of Rev. David and Ella Kidder Coggin. Losing both of his parents at an early age, he went to live with relatives at Tewksbury, Mass., later at Medford and Lowell in the same state. He never received a degree in the liberal arts and sciences, but, late in life, received the honorary A. M. from Dartmouth.

He began the study of medicine with Dr. Savory, of Lowell, well-known locally. In 1865-66 he attended a single course of lectures at the Long Island Hospital Medical College, and, later, another at the Harvard Medical School, from which institution he graduated in 1868. He then went to Paris, where he studied anatomy for one year.

Returning to America, he practised for a time at St. Louis, Mo. Then, moving back to Massachusetts, he settled at Salem, where he remained until he died.

He was a member of numerous medical associations, and especially active in the American Ophthalmological Society.

He wrote a large number of medical articles, chiefly on ophthalmology, and otology, nearly all of which were published in the *Boston*

Medical and Surgical Journal. An ever-present characteristic of these articles was their brevity. Hardly one was even a column in length. As a natural consequence, some of his most important contributions are over-condensed and obscure.

David Coggin.

Dr. Coggin is said to have performed, in the entire course of his eye and ear practice, more than 32,000 operations. It is only right to add, however, that among these were included all his minor operations, such as the removal of foreign bodies from the cornea, dilating the lachrymal punctum, etc.

He received a paralytic stroke in 1911, and, thereafter, was unable to practice again. He died May 7, 1913.—(T. H. S.)

Cohnheim's theory. A theory as to the origin of neoplasms; that all true tumors are due to faulty embryonal development. These embryonal cells do not undergo the normal changes, are displaced, or are superfluous. When favorable conditions are presented later in life they take on growth, with the formation of tumors of various kinds.

If, for example, during the fetal stage portions of the epithelium become nipped off and included in the connective tissue, these inclusions, if stimulated to activity in later life, give rise to a *cancerous* growth.

Cohn, Hermann. A celebrated ophthalmologist, known especially for his services to ocular hygiene. Born at Breslau, Germany, June 4,

1838; he at first studied natural science in general, both at Breslau and at Heidelberg, at which institutions the teachers that most influenced him were Helmholtz, Bunsen, and Kirchhoff. He received the degree of doctor of philosophy at Breslau, Oct. 20, 1860. He then studied medicine at Breslau and Berlin, receiving his medical degree at the latter institution in 1863. For the next three years he practised ophthalmology in Breslau. In 1868 he became docent, and in 1874 extraordinary professor, at the University of Breslau. Afterwards he was elected full professor in the same institution.

His writings, which are almost all devoted to the subject of ocular hygiene, are (mentioning the more important only) as follows: "*Examinations of the Eyes of 10,060 Schoolchildren, with Proposals for the Betterment of School-Arrangements Injurious to the Eyes*" (Leipsic, 1867); "*Gunshot Wounds of the Eye*" (Erlangen, 1872); "*Preliminary Efforts toward a Geography of Eye-Diseases*" (Jena, 1874); "*Schoolhouses and School-desks at the Vienna World's Fair*" (Breslau, 1873); "*Studies in Congenital Color Blindness*" (Breslau, 1879); "*Ocular Hygiene in Schools*" (Vienna, 1883); "*Hygiene of the Eye*" (English Trans. by Turnbull in 1886). Besides these very important books, he wrote at least 97 journal articles, almost all of which are devoted to the subject of ocular hygiene.

Cohn died in 1906 at the age of 68, having been professor of ophthalmology for 32 years. On Sept. 11, 1908, an interesting ceremony took place in the Jewish cemetery at Breslau, namely the dedication of a suitable monument to the memory of this celebrated ophthalmologist. A vast concourse witnessed the ceremony (for, in Germany, a great doctor is a great man), and on the monument appeared these modest, yet very appropriate words, which had been selected by Hermann Cohn himself:

"Augenkrankheiten zu verhüten
Betrachtete er als seine Lebensaufgabe."—(T. H. S.)

Cohn's embroidery patterns. This is a modification of the Holmgren test in which the author made use of various colored embroidery patterns, intended to confuse the red-green color-blind patient.

Cohn's test-types. In this well-known test of the vision of school-children and adult illiterates Cohn has arranged thirty-six Ш figures in such a way that they form six rows of six figures each, from left to right, and up and down. This allows for four different orders of succession of the figures, according to the position in which the square board is hung. This board is recommended by Cohn as a means of judging the amount of illumination of a room. He has also published "transparent test-types." These are similar to the

ordinary test-types, but are printed on transparent paper. They are intended to be placed between two glass panes and hung against the window, so as to be seen by transmitted light. This arrangement admits also of the types being seen reflected from a mirror, as for this purpose all that is required is to turn the back surface to the front. In a room which is sufficiently lighted, this may prove of some advantage, but, on the other hand, placing a patient with the face opposite to the window, or even to a mirror, may sometimes be a disadvantage. —(Norris and Oliver's *System*, II, p. 26.)

Coiter's corrugator. The corrugator supercilii muscle.

Coitus nervorum opticorum. (L.) Optic chiasm.

Col. (F.) Neck.

Colchicum. COLCHICUM AUTUMNALE. The ocular symptoms produced by preparations of this poisonous plant are principally mydriasis, with more or less defective reaction to light. Andreae (*Medicin. Zeitung*, 1834, No. 29, p. 135) reported miosis in a patient who drank a large quantity of the tincture of the seeds. Lewin and Guillery (Vol. 2, p. 943) relate a case of a boy who had keratitis, iritis and cataract (anterior polar) after eating colchicum seeds. The general intoxication was quite marked. The authors are in doubt as to whether the colchicum had anything directly to do with these eye symptoms.

In the *treatment of eye symptoms*—and the ophthalmologist has to deal with many cases of *gouty* infection, especially iritis and choroiditis—the therapeutic value of colchicum should not be forgotten. As A. F. Amadon properly says, rapid results follow the treatment of gouty eye diseases, either with colchicine alone or by the addition of $\frac{1}{64}$ grain of that alkaloid, given from four to six times a day, in conjunction with the iodides or salicylates in sufficient quantities to produce moderately free catharsis. The alkaloid, he adds, seems to be far superior to the tincture or wine of colchicum, and he has noticed that the more decidedly the case is of gouty origin, the more benefit will be derived from its use.

Cold, Application of. This remedial agent is a common and extremely useful application to the eye. The form of its application should depend upon the character and locality of the lesion. Iced applications are used in the severer forms of inflammation, when secretion is abundant, by means of gauze pads (7 or 8 thicknesses) or absorbent cotton about $2\frac{1}{2}$ inches in diameter. These pads are placed on the flat and smooth surface of a block of ice, which should be large enough to hold at least half a dozen, and the excess water wrung out before applying them to the eye. They must be moist but not wet,

in order to avoid the disagreeable chilling of the surface of skin from the water running over the face. The pad should be changed frequently and, as it quickly absorbs the heat from the inflamed parts, ought to be replaced by another pad with as little delay as possible, so that the eye will not be exposed any longer than absolutely necessary during the procedure.

In the less severe inflammations cold may be applied to the closed eyes, by means of a folded towel, using a basin of cold or iced water in place of the hot water. Cold or iced applications should not, as a rule, be used as long or as often as hot applications. In the milder forms of ocular inflammation five minutes is quite a sufficient length of time, although in the severe types of purulent conjunctivitis iced applications may be kept on for a longer period. Cold applications should not cause pain or discomfort to the eye; if they do they must be discontinued, or replaced by hot fomentations. The ice pack should never be applied to the eye for more than a few minutes at a time.

Cold is generally employed in superficial inflammations of the eyeball and lids, especially in hyperemias and inflammations of the conjunctiva, purulent and otherwise, but is to be avoided when the cornea becomes affected. It is also indicated in most injuries of the globe.

A. Duane believes that iced applications should be used in acute conjunctivitis, ophthalmia neonatorum (gonorrheal ophthalmia, traumatic conjunctivitis) as long as the lids are intensely swollen. Suspend the application when the skin of the lids begins to wrinkle, showing that edema is subsiding. Use it also in traumatic iritis.

Cold cream. Unguentum aquæ rosæ. Unguentum emolliens. Ceratum galeni. This simple but valuable ointment and excipient is prepared with spermaceti, white wax, expressed oil of almond, finely powdered boric acid and stronger rose water.

Although this preparation is not always made according to the official formula yet it generally forms a valuable base for eye ointments and is alone a useful application to the lid edges in diseases of those organs. Its consistency for medical purposes is improved if the proportion of white wax be varied according to the temperature or the season of the year. If it is to be used as a vehicle for metallic salts the boric acid may be omitted.

Cold, Exposure to. "Catching cold" has been held responsible for so many diseases with which it has probably no connection that one hesitates to discuss it as an etiological factor in ocular affections. However, nuclear paralysis, Bell's paralysis, retrobulbar neuritis

and other affections have been thought to arise from exposure to drafts and other forms of sudden chill of the body, while hyperemia of the conjunctiva has undoubtedly been set up by it, just as many ocular inflammations are aggravated by the same cause.

Cold in the eye. Catarrhal conjunctivitis.

Cold light. In making the most efficient (hot) artificial light known only about five per cent. of the energy produced by the combustion of coal is utilized. Nature is occasionally more efficient. Samuel P. Langley, as well as Ives and Coblentz, tested the lighting powers and efficiency of the firefly. As a result of these studies, we know that the firefly's efficiency is about 96.5 per cent.; in other words, its light is well-nigh "cold" because less than four per cent. is wasted in the form of heat. François Dussaud (*Harper's Monthly Magazine,* July, 1913) has achieved a noteworthy result in enabling the physicist to give us a light which will be both cheap and agreeable. Paradoxically, the *cold* light of Dussaud is produced at an unusually high filament temperature. He has devised a very simple and ingenious method of preventing the dissipation of that heat into space.

"Cold light enjoys five principal advantages over ordinary light. In the first place there is no danger of it burning or setting anything on fire. Concentrating lenses and reflectors are employed, with the result that the lamps consume a hundred times less current than any other electric light of the same illuminating power. Again, it can be produced by any kind of electric system. Then, if you cannot use the city electricity, a tiny battery or an inexpensive pocket accumulator will do, or you can obtain sufficient motive power from the kitchen faucet, a gas-burner, or a petroleum lamp; and if all these means fail, the foot, or any small animal—a squirrel in a turning-cage, for instance—will furnish all the needed motive power, for, as has just been stated, this lamp requires a hundred times less current than the ordinary electric lamp. The final advantage is found in the fact that this light contains ultra-violet rays, obtained for the first time without heat and with a hundred times less electricity than is required by other methods. The full importance of this will be realized when it is remembered that these rays are being employed more and more every day in medicine and chemistry for syntheses, sterilization, and germicides.

"The application of cold light to moving-picture shows is of the highest importance. Hundreds of persons are killed every year by the fires occasioned by the present system. But with cold light there is no danger of this sort. A small, cheap lamp, whose motive power

may be a little accumulator or a single battery cell, replaces the expensive, complicated, and cumbersome process now in use, and will tend, along with Edison's new kinetophone, to make film-plays the school, newspaper, and theater of the future. Furthermore, cold light renders possible, in this connection, two improvements until now quite unknown. Because the light is cold, a film can be slowed down or even entirely stopped, thus fixing on the screen the different phases of a movement and letting the eye repose, without interrupting the spectacle, at a moment when the film represents only objects that are stationary. In this last case some five or six dollars is economized per minute, for more than twenty yards of film have to be reeled off in order to project during a single minute an object of a person in repose or a landscape. Thus is obtained a practical combination of fixed and moving pictures, which produces most artistic effects. It also enables us to work two cinematographs projecting alternately in order to avoid scintillation, or projecting simultaneously red and green images and reproducing natural colors, thus relieving the human eye, accustomed to receiving the fundamental colors simultaneously, from all physiological fatigue.

"Cold light can be applied in medicine. The arc or any other light must be held, on account of giving out heat, at a distance of several centimeters from the object to be illuminated, whereas a cold-light source can be brought within a few millimeters. Now, lighting power being in inverse ratio to the square of the distance, it results that a source of cold light of twenty-five candle-power at a distance of five millimeters equals five thousand candles of hot light at seven centimeters. The hand, brought in contact with these twenty-five candle-powers contained in a volume of ten cubic millimeters, becomes transparent, the flesh and bones taking on the appearance of a translucent, whitish-pink body, where the blood-vessels stand out in violet blue. The human eye can bear these luminous rays only for a few seconds even when they have passed through the thickest part of the hand. Care should be taken, therefore, not to withdraw the hand during the experiment, as there would be considerable danger in having the light strike the eye direct. A blood-red hue is spread over the human face by this light that has passed through the hand, and this hand, thus lighted up and made transparent, renders possible for the first time a spectroscopic analysis of the blood circulating in a sick person during the different phases of the treatment. This hand can be studied under the microscope as though it were a preparation, and can be photographed in colors or in black on sensitive plates, one for each color; that is to say, the flesh appears on one plate, the

blood-vessels on another, and so on. Thus by the aid of colored and stereoscopic photography we arrive at topographical anatomy. Foreign bodies, as, for example, small shot in a wounded person in a shooting accident, can now be discovered, which could not have been three years ago. Such a shot appeared as a black speck in the pink flesh between two blood-vessels. By a special arrangement of the apparatus it is possible to operate in the thicker parts of the body. Thus, in the case of the arm, several rectilinear fibers lying very close together were distinguished at a distance of five millimeters from the glass.

"Cold light has been perceived by a person afflicted with blindness, but preserving vestiges of sight which had not been suspected because of lack of a sufficiently strong source of light, or because this light, on account of its heat, could not be brought near enough to the eye. This opens up an interesting field of study and work. Now it may be possible to impart a knowledge of light to those born blind but retaining a slight trace of vision, or to educate anew those rendered sightless by accident."

Coleoptera. This family of insects includes *Cantharis vesicatoria* (Spanish fly), *Meloë detonans* (a Mexican insect producing cantharidin), *Blatta orientalis* (the cockroach), and several other animals whose ocular relations are discussed under their several headings.

Colera. (It.) Cholera.

Colesterina. (It.) Cholesterin.

Colestearina nel corpo vitreo. (It.) Cholesterine in the vitreous.

Colestearina nella lente. (It.) Cholesterine in the lens.

Coley's fluid. This remedy consists of the mixed toxins of the streptococcus and bacillus prodigiosus. Its use in combatting the growth of sarcomata is empirical, and it may be said to be justified in cases where an inoperable secondary growth follows the unsuccessful surgical removal of the primary neoplasm.

W. Luedde reported the treatment of two such cases to the Ophthalmic section of the St. Louis Medical Society, May 7, 1913. The first case, white, age 13, in which a recurrence of the growth happened after two attempts at removal of the tumor mass and again after a complete exenteration of the orbit, has remained free from any sign of a relapse for nearly six years. Except during an acute inflammation of the nasal sinuses, which caused a temporary swelling, there has been no disturbance whatever in the right orbit. The operative defect is perfectly covered by a flap from the right cheek.

A female, white, age 22, was brought on account of a firm swell-

ing at upper-inner angle of the right orbit. After nearly two months, during which there was a slow but positive increase in the size of the tumor, a gradual increase of subjective suffering as well as a slight decrease in the clearness of vision in the affected side, the patient consented to an exploratory operation, which showed that the process extended from the ethmoid and frontal sinuses back into the orbit too far to permit complete removal without interference with the right eye. Three months later an attempt was made to remove the mass at the upper inner angle of the orbit by removal of the frontal eminence—exposing the frontal sinus, also removing the nasal bone and scraping the ethmoidal sinuses. When the outer plate of the frontal sinus was removed, it was found that the inner plate was already eroded and that curettage of the frontal sinus contents showed brain tissue among the fragments. The case was then given up as hopeless so far as the surgical removal of the growth was concerned. The unexpected happened in that the patient recovered with little disturbance from this operative interference. Even the removal of brain substance caused no considerable shock.

It was decided to administer Coley's fluid. The effect of its use was to stop any increase in size of the mass. When last seen (Sept., 1913) she was apparently in excellent health. Her sight was normal in each eye and she had good binocular vision in spite of the condition of the affected eye. See, also, **Seropathy.**

Colibacillosis. The morbid condition due to infection with *bacterium* (or *bacillus*) *coli.*

Colibacillus. The bacillus coli (q. v.).

Collaform. A formaldehyd-gelatin preparation intended as an application in lid wounds.

Collapsed cornea. This term is applied to that sinking in of the cornea which occurs in certain lesions or after operations for cataract. Instead of being normally curved the cornea looks as if it were pressed in. This condition seldom persists for a long time; as a rule the normal curvature returns in a few minutes or hours. The cause is the rigidity of the sclera which occurs in senile and decrepit people. If the lip of the wound lie properly the condition disappears without treatment. If, however, it does not improve within a comparatively short time, or if there has been much loss of vitreous, intraocular injection of warm, sterile physiological salt solution is indicated.

Collapsules. See **Tubes, Collapsible.**

Collargol. See **Argentum colloidale.**

Collateral fissure. The inferior occipito-temporal, or collateral, fissure

is a complete fissure which gives rise to the *eminentia collateralis* in the descending horn of the ventricle, and cuts deeply into the temporal and occipital lobes.

Collateral hyperemia. In some cases of conjunctival or scleral congestion associated with circumcorneal or ciliary injection the former predominates, and to a large extent conceals the latter; in which case we have collateral hyperemia.

Colle. (F.) Glue.

Collet. (F.) A narrowing resembling a neck or a collar.

Collétique. (F.) Agglutinative.

Colliculus nervi optici. Colliculus opticus. Optic papilla or disc.

Collimate. In *optics,* to bring into the same line, as the axes of two or more lenses in an optical instrument.

Collimating lens. A lens like that of the collimator of a spectroscope, the object of which is to render incident rays of light parallel. See **Collimator.**

Collimation. The accurate adjustment of the line of sight of a telescope. Two telescopes are said to be in collimation when their optical axes coincide. *Line of collimation,* the line in which the optical axis of the telescope ought to be.

Collimator. A fixed telescope with a system of wires at its focus, and so arranged that another telescope can readily be brought into collimation with it, when an observer at the eyepiece of the latter can look into the objective of the former and see the cross-wires or slit in its focal plane. The intersection of the wires of the collimator is used as a standard point of reference.

Collinear. Lying in one and the same straight line.

Collinear space-systems. In *optics*, divisions of space between which a point-to-point correspondence is established through the directions of rectilinear rays in the corresponding plane-fields of the object-space and image-space; each so-called *plane-field* being the totality of all the points and straight lines situated in an infinitely extended plane in any meridian containing the optical axis. This correspondence between the object-space and image-space is called *collineation,* the fundamental requirement of *optical imagery.* Its application to the theory of optical instruments is most exhaustively treated in Prof. Southall's work on the *Principles and Methods of Geometrical Optics,* wherein it is defined as follows:

"Two space-systems E and E′ are said to be 'collinear' with each other if to every point P of E there corresponds one, and only one, point P′ of E, and to every straight line p of E, which goes through P, there corresponds one straight line p′ of E′ which goes through

P′." In the geometrical theory of optics the two spaces E and E′ are designated as the *object-space* and the *image-space*, respectively. The *image-space* is the extent of space actually or virtually traversed by the *effective rays* (q. v.) that are directed toward each point of the image produced by an *optical system* (q. v.). The vertexes of the ray-bundles which actually or virtually intersect points of the image are located in the image-space, whereas, the plane of the image itself may be located in the object-space; yet, the image-plane is always identified with the image-space, wherever it may be, since the ray-bundles, producing the image-points, either actually or virtually traverse the image-space. Therefore, the object-space and the image-space are not at all times separate and distinct parts of space, as they may penetrate and include each other, so that a point, ray or plane may be regarded as belonging to either of the two space-systems. A point, ray or plane in space, according as it is regarded as belonging to one or the other of the two space-systems, is called *object-point, object-ray* and *object-plane*, or *image-point, image-ray* and *image-plane* (q. v.). Since the relation between the object-space and the image-space is perfectly reciprocal, there is no essential difference between them.—(C. F. P.)

Collineation. A term introduced by Moebius to signify a point to point correspondence by means of rectilinear rays between the object-space and the image-space. It is the fundamental and essential requirement of optical imagery. See **Aplanatic**; and **Collinear space-systems.**

Collins' magnifier. This effective instrument is a binocular magnifier, mounted like the Hess loupe on a spectacle frame and self-illuminated by means of an electric lamp.

Collirio. (It.) Eyewater, or collyrium.

Collodion. Flexible collodion. Collodium. Contractile collodion. The various collodions in commerce are chiefly solutions of pyroxylin (gun cotton) in ether and alcohol and are intended for external applications. Cantharidal collodion is used to blister the skin; all the others are used as dressings and for fixing them. They are to be applied by means of a small brush; the ether and alcohol evaporate and leave the surface covered by a thin film. Flexible collodion is suited to abrasions, as an addition to bandages, cotton-fibre or gauze dressings in plastic operations, etc.

Collodion, Acetone. This useful mixture is prepared from gun-cotton, 5 parts; ether, 10 parts; alcohol, 10 parts; acetone, 20 parts; castor oil, 6 parts. It is more elastic than the ordinary flexile collodion (q. v.).

Collodion, Iodized. See **Iodine.**

Collodion, Iodoform. Flexile collodion intimately mixed with 5 per cent. of iodoform.

Collodiotype. A photograph produced by the collodion process.

Colloid. A substance of the gelatine class which does not, when in a state of solution, pass easily through such membranes as parchment paper.

Colloid bodies. Drüsen. Hyaline bodies. Verrucosities. Colloid excrescences. Corpora arenacea. Concretions. Drüsen bildung. Speaking of the confusion which has resulted from the indiscriminate use of the terms "colloid," "hyaline," and "amyloid" Parsons (*Pathology of the Eye,* Vol. I, p. 96) endeavors to bring order out of chaos. Degenerative changes, leading to the formation of homogeneous material, he says, are of frequent occurrence in all parts of the eye, as also elsewhere in the body. The material varies very much in its staining reactions, undoubtedly owing to its variable chemical constitution. In all probability these substances are entirely formed from exudates or secretions, i. e. from the non-living products of living cells. In some cases this must be considered a physiological process, as, e. g., when the deposit in Descemet's membrane is laid down by the agency of the endothelial cells, the lens capsule by the epithelial cells, Bruch's membrane by the pigment epithelium of the retina, etc. In others it is a pathological process, which may be allied to the physiological, as in the formation of the so-called "colloid" bodies of the choroid, etc., but is more commonly due to chemical changes in exudates derived from the lymph or blood-plasma. Most of these exudates are proteids, or consist chiefly of proteids. They are inert, dead material, lying amongst living cells, and their subsequent fate depends upon their environment. This, in turn, varies with the general conditions of the organism, as well as with the exact local disposition, such as relationship to vessels, cells, etc. Hence it is not surprising that the changes these exudates undergo differ in widely divergent ways. Some are mere plasmatic coagula, others contain living or dead leucocytes. The first stage is often the formation of a network of fibrin, and this may simply disappear, forming the pabulum of rapidly growing fibroblasts, or melting by ferment action into soluble proteids which are carried off in the lymph-stream. In less active conditions—marasmic, senile, and so on—the exudates stagnate. They then undergo chemical changes, whereby they slowly alter from substances giving all the proteid reactions to substances which give only "albuminoid" reactions, and these vary much amongst themselves. Some have fairly definite colour reac-

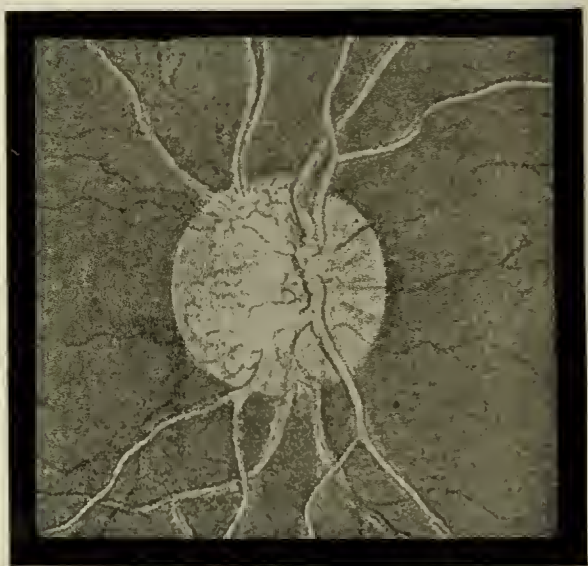
tions; if they stain mahogany-brown with iodine and pink with methyl violet, they are called amyloid, and this seems to be a fairly stable entity. Often, however, the reaction is indeterminate; parts fail to show the reaction, others show it well, whilst yet others give intermediate tints. We are dealing with mixtures, or with bodies in a state of chemical change. These facts must be carefully borne in mind whenever we speak of hyaline bodies or degeneration, etc. The earlier observers did not always realise them, and it will be necessary to refer to their views; but many of the apparent contradictions are due to these facts, and many of the divergent views are but the expression of divergent processes.

Hyaline Degeneration. x 34. (Parsons.)

From a partial anterior staphyloma. The scar tissue on the surface is transformed into whorls and clumps of hyaline material, which contains calcareous salts in parts. The masses are pushed up into the epithelium, which is thus made very irregular, though the levelling tendency is still apparent. Towards the right is a vesicle in the epithelium, containing hyaline substance. The deeper layers of the substantia propria are infiltrated and vascularised. Below is the adherent degenerated iris.

These colloid or hyaline changes are found as advanced or senile degenerations in all parts of the ocular apparatus. They are seen in the conjunctiva (pinguecula), sclera, cornea (for example, the nodular opacities of Fuchs), ciliary body, choroid, retina and optic nerve, and, as such, will be discussed under appropriate headings. A few examples of this degeneration are pictured in the text. It may be added here that colloid bodies appear as spheric deposits imbedded in the optic disc or bordering its periphery. They are

translucent and have been compared to "half-soaked grains of tapioca" (Gifford). To direct ophthalmoscopy they appear two or three millimetres in diameter, and are best observed by throwing the light to one side of them (Liebreich). In rare instances the hyalin masses may cover the nerve-head, as in the case recorded by Nieden (see the figure). The disease may occur in eyes which are otherwise entirely normal, or in association with albuminuric retinitis, retino-chorioiditis, or retinitis pigmentosa. As regards the etiology of the affection, Cirincione says: "The first cause of this hyalin transformation and subsequent calcareoûs deposit in the papilla, however, remains to be determined." Colloid formations found in the nerve-head are quite distinct from the excrescences which spring from



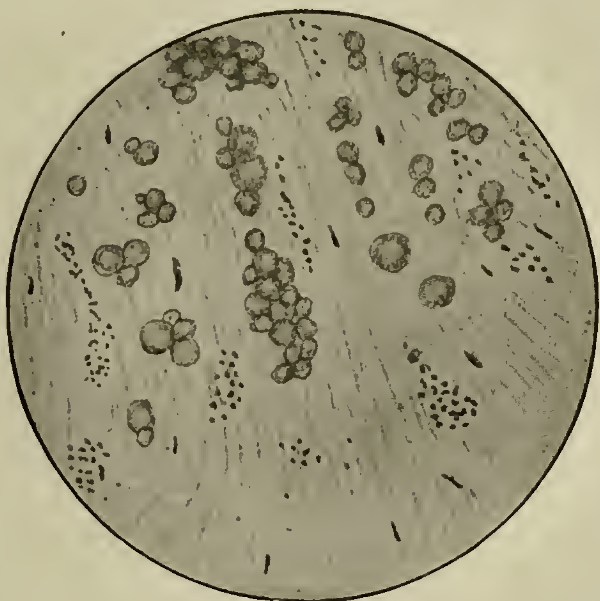
Hyalin Bodies in the Optic Disc. (Nieden.)

the lamina vitrea of the chorioid. While hyalin bodies are more frequent among elderly persons, they have also been observed in children.

A rare condition of the macular region, which is symmetric and which may be mistaken for central choroiditis, is the occurrence of colloid formations resembling those found in the nerve-head. In a case observed by the author both maculæ were occupied by rounded, yellowish bodies lying beneath the retinal vessels, and presenting a mulberry-like appearance. The patches were oval and equal in length to two disc diameters. The patient was a man, aged 41 years, and vision was normal. Three similar cases have been seen by de Schweinitz. Nettleship has described a similar case as central, guttate choroiditis with normal vision. His patient showed "a number of small, perfectly circular, pale, grayish-yellow spots thickly congre-

gated at the yellow-spot region, and more thinly scattered all around that part, reaching on the nasal side as far as the disc." According to Dimmer, the change is a simple colloid degeneration. The excrescences are located in the lamina vitrea of the choroid. The condition does not call for treatment. Choroiditis can be excluded by the fact that vision is normal.—(J. M. B.)

As one of the many examples of colloid deposits in the choroid Coats reported to the Oph. Soc'y. U. K. in 1910 the history and anatomical investigation of one of his cases, affecting the membrane of Bruch. The eye was from a patient, æt. 58, who had achondroplasia and double glaucoma. In the right eye the media were clear, the fundus was seen strewn with flat, scaly, irregular, white and



Microscopic Section Showing Hyalin Bodies in the Nerve-Head. (Ball.)

grey areas, with a slightly wavy surface, and with a distinct glitter on moving the light. The borders were sinuous and rimmed with pigment. The choroid was degenerate. The left eye was blind, with the retina detached; so it was excised. Sections showed that the areas were due to an aberrant type of colloid excrescences. The ordinary round nodules were seen, and in addition flakes and spongeworks of colloid. In this eye it was noteworthy that the corneo-iridic angle was quite free and there was no apparent obstruction to drainage. He thought the glaucoma possibly due to a disproportional quantity or altered quality of the secretion.

Giri (*Ophthalmoscope,* July, 1913) advocates the employment of the term "concretion" instead of "hyaline" or "colloid" to describe these deposits in the optic nerve—especially those in the intervaginal

space. He says that owing to the confusion arising from the use of arbitrary names, as "colloid," "hyalin," and "amyloid," because of the variability of the staining reactions, it is suggested that the names be based on the anatomic position and histogenesis, which are constant and convey a definite intelligible idea to the mind.

A well formed concretion in the intervaginal space, as seen microscopically in a section, has a regular rounded structure. It has a center of very fine granular débris disposed in closely set, well-defined, regular concentric layers. The center is marked off from the rest by its greater refractility and is encircled by a deeper-stained ring, in which the concentric lamellation is less defined, and the débris is not so finely granular as in the center. The succeeding ring stains deeper still, is composed of coarse granules and looks like a wavy fringe of tangled curly hair interspersed with faintly staining, malformed, breaking-down nuclei. The whole is enclosed in a capsule, which presents a fine fibrillary appearance, stains lightest and contains here and there a degenerating nucleus. Outside the capsule are to be seen concentrically arranged rows of nuclei, which are short or long ovals, whose long axes run parallel to the circumference of the circle which they form. The smallest concretions often appear homogeneous. The diameter of these concretions varies from 22 micra to 110 micra, the average concretion having a diameter of 88 micra. They go by the name of "corpora arenacea."

Microscopically various stages of development of the concretions can be seen. Some young concretions give evidence of their arising from a gradually developing hyalin degeneration of the connective tissue trabeculæ.

Corpora arenacea occur very seldom in the intervaginal space. They are mentioned only three times in the literature. They are never found in young patients, and have no pathologic significance in this space other than that of a kind of senile change. Corpora arenacea in the intervaginal space do not fuse, but tend to remain distinct.

Notwithstanding the fact that the corpora amylacea develop only within the nerve substance, and hence are never found in the intervaginal space, they have been confused with the corpora arenacea of this space, owing to the fact that a concentric structure, as in the genuine corpora amylacea of plants, may be present in both, and that they may both react similarly to stains.

Drüsen in the optic nerve head have erroneously been put under the same group as corpora arenacea.

A case of drüsen in a man, 42 years of age, with iridocyclitis fol-

lowing a perforating injury incidental to a dynamite explosion, is described. The eye was enucleated and a study made of a series of sections. A large number of concretions of varying size were found lying deep below the surface of the papilla in front of the lamina cribrosa. They are all made up of a fine granular débris, disposed in delicate concentric layers. The granules are somewhat coarser towards the periphery of the concretions. The large concretions have a well-defined, irregularly nodular outline, and the body is composed of a series of concentric systems.

Colloid Bodies in the Choroid. x 200. (Coats.)

Two large laminated "colloid bodies," stained with hematoxylin and eosin. Beneath them, and apparently quite unconnected with them, is a fine, highly refracting zig-zag line—the outer, elastic layer of the membrane of Bruch. Note the unbroken layer of flattened, partially depigmented epithelium covering the nodules.

The larger ones are conglomerates of smaller ones, the better the fusion the less marked off are the concentric systems from one another. In the neighborhood of and between the smaller conglomerates, the neuroglia cells appear closely packed in a number of layers—an appearance probably due to neuroglia strands getting pushed together by the growing concretions.

Giri agrees with Streiff, that an alteration in the constitution or a disturbance in the circulation of the lymph in the eye lies at the root of drüsen formation. This change may come on as one of short or long duration, may be general or local, leading to small deposits,

which afterwards grow by the same chemical process which caused the initial deposition of insoluble albuminoid substances from the lymph. That the deposition takes place in the neighborhood of the central vessels or at the edge of the disc, as a rule, is probably because the edge of the disc and the surface of the vessel walls act as points of resistance to the lymph stream and as scaffolding for drüsen formation.

These hyalin or colloid bodies also probably form the principal ophthalmoscopic signs in most examples of Mooren's retinitis and of Tay's (guttate) choroiditis. Alt. (*Lectures on the Human Eye,* 1880) believes them to be mainly the starting point for ossification of the choroid, while they are known to be associated with retinitis pigmentosa. Both Ernest Thomson (*Ophthalmoscope,* Jan., 1913) and George Oliver (*Ibid.,* page 716, Dec., 1913) cite cases in proof of the latter assertion. The colored plate shows the changes in the fundus exhibited by the patient of the latter writer.

The best discussion of the whole subject is that given by Parsons (*Pathology of the Eye,* Vol. 2, p. 470), and by Coats (*Royal Lond. Ophth. Hosp. Rep.,* 16). (See, also, Volume 1, p. 332 of this *Encyclopedia.*)

Colloide Entartung. (G.) Colloid degeneration.

Colloma. (L.), n.n. A cystic tumor with gelatinous contents.

Collotype. Albertype. Artotype. Phototype. A photomechanical process by which prints in greasy ink are obtained by means of a film of gelatine in relief.

Collyre. (F.) Eyewater or collyrium.

Collyre adoucissant. (F.) A collyrium made of 2 parts of gum arabic, 3 of mucilage of *Plantago psyllium* seeds, and a sufficient quantity of rose-water and plantain-water.

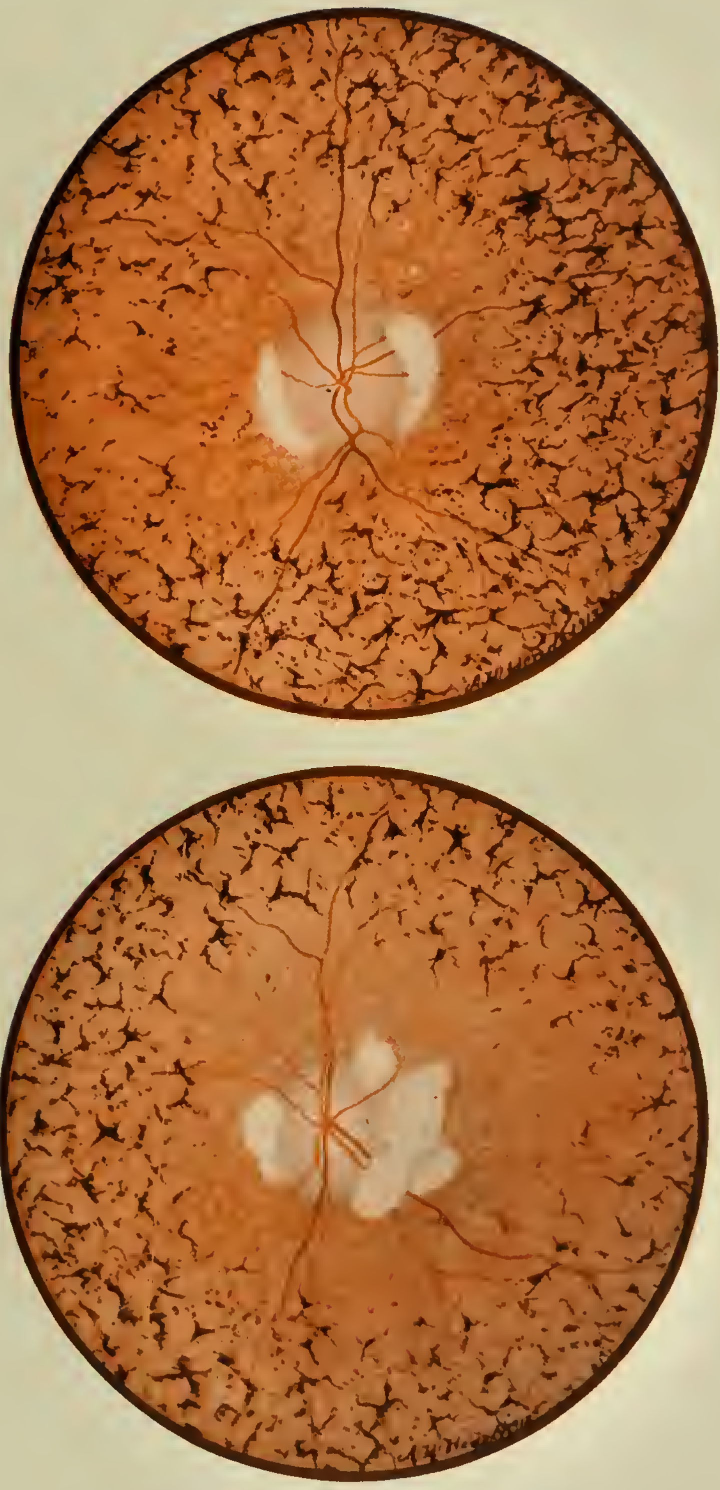
Collyre alumineux. (F.) Another name for *aqua ophthalmica aluminosa,* or alum water.

Collyre alumineux plombique. (F.) An old French preparation, known as *"l'eau de la Duchesse de Lamballe.*

Collyre antiscrofuleux. (F.) An old preparation prescribed by Baudelocque, made by dissolving 150 parts of extract of soot in 1,877 parts of vinegar and adding 6 parts of extract of red roses. It was used in scrofulous ophthalmia. Négrier also had a mixture of the same name, made of 2,000 parts of decoction of walnut, and 1 part each of Rousseau's laudanum and extract of belladonna.

Collyre astringent. (F.) A name given both to the "collyre au sulfate de zinc," and to the *aqua ophthalmica aluminosa.*

Collyre astringent camphré. (F.) Camphorated astringent collyrium;



Hyaline or Colloid Bodies at the Optic Disc in a Case of Retinitis Pigmentosa.
(G. H. Oliver.)

made by dissolving 3 parts of zinc sulphate in 2,000 parts of rose-water and adding a few drops of camphorated brandy.

Collyre astringent opiacé. (F.) An opiated astringent collyrium. It was made of 1 part of extract of opium, 2 parts of zinc sulphate, and 1,000 parts of rose-water; or 1 part of cadmium sulphate and 5 parts each of tincture of opium and distilled water. It was for many years popular as a remedy for opacities of the cornea and for chronic ophthalmia of various kinds.

Collyre astringent résolutif. (F.) Astringent resolutive collyrium, made of 1 part of zinc sulphate and 400 parts of infusion of elder.

Collyre astringent vitriolisé. (F.) Vitriolized astringent collyrium. This is a preparation official in the Edinburgh *Pharmeopcia* of 1826. It was made by dissolving 16 grains of zinc sulphate in 8 ounces of water, and adding 16 drops of dilute sulphuric acid.

Collyre azuré. (F.) This eye lotion is associated with the name of Scarpa. It is a collyrium made by dissolving 1 part of copper acetate and 12 parts of ammonium chloride in 1,250 parts of lime-water, and, after an interval of several hours, filtering.

Collyre bartique. (F.) A solution of barium chloride diluted and thickened with quince mucilage. It was employed as a remedy for scrofulous blepharitis.

Collyre boraté. (F.) A name given to a number of eyewaters. Perhaps the best known is the one said to have been extensively prescribed by Desmarres, which contains from 1 to 5 parts of sodium borate, 1,200 parts of distilled water, and 50 parts of distilled cherry-laurel water. It was used lukewarm, in various forms of conjunctivitis.

One by Daunercy, a mixture of 1 part of sodium borate, 10 parts of pure glycerin, 5 parts of distilled cherry-laurel water, and 85 parts of distilled water; used in chronic ophthalmia.

One by Foy, a mixture of 2 parts of borax and 4 parts of sugar dissolved in 125 parts of rose-water.

Another by Sichel, a mixture of 1 part of borax and 8 parts of quince mucilage dissolved in 60 parts of cherry-laurel water.

Still another by Bridault (synonym *eau de Provence, eau de l'épicier, eau de la Duchesse d'Angoulême*), a mixture of 1 gramme each of zinc sulphate, rock candy, and iris, 200 grammes of water, and 20 drops of alcohol. All the foregoing eye waters were used in various diseases of the external eyes, but especially in conjunctival infections.

Collyre cathérétique. (F.) This preparation was made by mixing 10 parts of silver nitrate with 480 of distilled water, and adding 30 of Sydenham's laudanum.

Collyre clamant. (F.) Anodyne collyrium.

Collyre contra la conjonctivite. (F.) An eyewater advised by Sichel, eontaining 1 part of erystallized lead aeetate and 200 parts of distilled water; to be used mostly in simple or eatarrhal eonjunetivitis.

Collyre contre la conjonctivite chronique. (F.) Another eyewater proposed by Siehel, eontaining 0.05 gramme of eopper sulphate, 10 grammes of distilled water, and 6 drops of Sydenham's laudanum.

Collyre contre les blépharites. (F.) A favorite prescription of Siehel, made by mixing 0.05 gramme of corrosive sublimate with 30 grammes of distilled water, 4 grammes of quinee mueilage, and 6 drops of liquid laudanum.

Collyre contre les taies de la cornée. (F.) An eyewater reeommended by Maitre-Jean, a preparation containing 2 parts of powdered caustic potash and 50 of walnut-oil. To be applied lightly with a brush to leucomata and other opaeities of the cornea.

Collyre contre l'ophtalmie. (F.) A eollyrium used in various forms of conjunetivitis, made by dissolving 2 parts of atropine sulphate and 5 parts of pure crystallized zinc sulphate in 2,500 parts of rose-water.

Collyre contre l'ophtalmie puriforme des nouveaux nés. (F.) A collyrium employed in ophthalmia neonatorum, preseribed by Réveillé-Parise, and made by dissolving 1 part of silver nitrate in 300 parts of distilled water.

Collyre cuivrique. (F.) A solution of 1 part of morphine sulphate, 5 parts of eopper sulphate, and 10 parts of alum in 1,000 parts of water. It was used as a lotion to remove opaeities of the eornea.

Collyre d'Ammon. (F.) A eollyrium containing zine cyanide, gum arabie, blaek-cherry water, and laudanum.

Collyre de Beer. (F.) A eollyrium containing solution of lead subaeetate, rose-water, and spirits of rosemary.

Collyre de Benedict. (F.) A collyrium made from *Viola tricolor* and extraet of opium.

Collyre de conicine. (F.) Prescribed by Mauthner. This preparation contains from 1 to 3 drops of eonieine, 25 grammes of distilled water, and 8 grammes of quinee mueilage. It was reeommended for serofulous ophthalmia.

Collyre d'Erhard. (F.) A solution of borax in elder-water.

Collyre de Fischer. (F.) This eyewater is a solution of zinc sulphate and ammonium ehloride in a mixture of saffron-water and camphorated alcohol.

Collyre de Graefe. (F.) This well-known eyewater is a solution of zine sulphate (with a little laudanum) in mueilaginous rose-water.

Collyre de Henderson. (F.) As used in France, this preparation con-

tains 1 part of strychnia, 40 parts of dilute acetic acid and 300 parts of distilled water.

Collyre de Himly. (F.) A solution of from 2 to 6 grains of potassium carbonate in 1 ounce of water.

Collyre de Hufeland. (F.) A collyrium made by mixing 1 part of tincture of stramonium with 24 parts of water.

Collyre de Janin. (F.) An eyewater made of 1 part of zinc sulphate, 480 parts of plantain-water and 60 parts of quince mucilage.

Collyre de Jungken. (F.) A collyrium containing calomel, sugar and opium.

Collyre de Krimer. (F.) This eye lotion contains 1 part of hydrochloric acid, 4 parts of quince mucilage, and 240 parts of rose-water. It was supposed to be useful for dissolving small iron particles that enter the eye and must be removed or washed away immediately.

Collyre de Neumann. (F.) A compound made by macerating arnica flowers in vinegar and then saturating the macerate with ammonium carbonate. It was prescribed for "amaurosis."

Collyre de Plenck. (F.) An eyewater made by dissolving borax and sugar in rose-water.

Collyre de Richter. (F.) An emollient collyrium made by beating a mixture of white of egg and rose-water into a froth.

Collyre de Rust. (F.) A collyrium made by mixing together vinegar of lead, elder-water, and tincture of opium.

Collyre des alpes. A French proprietary remedy for external diseases of the eye, said to be "astringent and antiseptic."

Collyre des Bénédictines. (F.) See **Collyrium of the Benedictines.**

Collyre de Scarpa. (F.) An eyewater compounded of 180 grammes of distilled plantain-water, 6 drops of solution of lead subacetate, 15 grammes of gum Arabic, and 9 drops of alcohol.

Collyre de Stark. (F.) A collyrium made by dissolving an indefinite amount of lead acetate in rose-water.

Collyre de Tenque. (F.) This eyewater was made by dissolving lead acetate and ammonium chloride in rose-water.

Collyre de Tunnermann. (F.) This collyrium was made by dissolving 3 parts of lead acetate in 48 parts of water and adding 2 parts of solution of caustic potash.

Collyre de Velpeau. (F.) This eyewater was compounded of 1 part of nitrate of silver in 16 parts of water, and was used in purulent ophthalmia.

Collyre gazeux de Fumari. (F.) A gaseous collyrium made by adding 4 parts of distilled water and 1 part of sulphuric ether to 1 part of ammonia-water. In cases of ophthalmic headache it is directed that

the fuming mixture be held beneath the eye so that the vapors may act upon the eye and the forehead.

Collyre iodé. (F.) Boinet's iodized collyrium. It is made of 100 parts of tincture of iodine, 1 part of tannin, and 250 parts of distilled rose-water.

Collyre ioduré. (F.) A solution of 1 part of iodine and 50 parts of potassium iodide in 1,000 parts of water. It is employed to remove opacities of the cornea, as well as to dissolve particles of iron or steel that enter the eye.

Collyre narcotique. (F.) Foy's eyewater; which contains 1 part of extract of belladonna, 305 parts of extract of opium, and 6,250 parts of infusion of hyoscyamus.

Collyre opiacé. (F.) A collyrium made by dissolving 4 parts of aqueous extract of opium in 1,920 parts of rose-water; or by mixing 2 parts of aqueous extract of opium, 10 parts of quince-seed, and 1,920 parts of rose-water.

Collyre répercutif. (F.) The eyewater of Gaubins, a collyrium containing 500 parts, each, of rose-water and plantain-water and 3 of crystallized lead acetate. It was supposed to be of especial value in beginning inflammations of the eyelids.

Collyre résolutif opiacé. (F.) A resolvent eyewater with opium. It was made by dissolving 1 part of lapis divinus in 2 parts of water, adding to the solution 2 parts of Sydenham's laudanum, and mixing well.

Collyre rouge. (F.) The so-called red collyrium of Franck. This eyewater is made by digesting for 24 hours 1.25 gramme of potassium carbonate and 0.5 gramme of camphor in 60 grammes of distilled celandine-water, filtering and adding 24 drops of tincture of aloes.

Collyre sec aloétique de Boerhaave. (F.) The dry, aloetic eye-powder of Boerhaave, made by mixing 3 parts each of aloes and calomel with 400 of powdered sugar.

Collyre sec ammoniacal. (F.) A gaseous counterirritant made by mixing 1 part of ammonium chloride, 480 parts,, each, of slaked lime, vegetable charcoal, and cinnamon, 18 parts of cloves, and 30 parts of Armenian bole. This powder is placed in a ground-glass-stoppered bottle, and a few drops of water poured upon it. It is then applied as a remedy to the eye like smelling-salts to the nose—by opening the bottle and moving it from side to side under the affected eye. It is employed in "cases of chronic ophthalmia."

Collyre sec au calomel. (F.) An old and effective dusting remedy for certain forms of chronic conjunctivitis. An impalpable powder is

made by triturating together equal parts of calomel and powdered sugar.

Collyre sec de Beer. (F.) This collyrium contained 1 part each of burnt alum, zinc sulphate, and borax, with 3 parts of sugar. It was employed as a remedy for opacities of the cornea.

Collyre sec de Boerhaave. (F.) One of Boerhaave's favorite prescriptions—a collyrium containing 16 parts of powdered tin, 1 part of iron sulphate, and 28 parts of sugar.

Collyre sec de Dupuytren. (F.) A powder for making a collyrium; containing 1 part each of tutty (zinc oxide), calomel, and rock candy.

Collyre sec de Graefe. (F.) A powder for making a collyrium; containing 1 part, each, of red oxide of mercury and white agaric, combined with 15 parts of sugar.

Collyre sec de Récamier. (F.) A dry powder for making a collyrium; containing equal parts of white sugar and zinc oxide.

Collyre sec de Velpeau. (F.) A dry dusting powder, containing mostly calomel.

Collyre sédatif. (F.) Anodyne collyrium.

Collyres gazeux. (F.) Vaporous collyria, or gaseous eyewaters.

Collyres mous. (F.) A class of collyria; mostly ophthalmic ointments.

Collyres secs. (F.) Dry collyria; used either as dusting powders, or when dissolved in water or other fluid to make eyewaters. For example, the collyre sec of Dupuytren is made by mixing 1 part each of zinc oxide, calomel and sugar.

Collyre stimulant. (F.) A collyrium made by mixing together equal parts of solution of ammonium acetate and water.

Collyre styptique. (F.) Aqua ophthalmica aluminosa (q. v.).

Collyre végéto-minéral. (F.) A solution of sodium chloride in a decoction of oak-bark.

Collyrium. (Plural, *collyria.*) EYE-LOTION. EYE-WASH. EYE-WATER. In ancient times a collyrium, properly speaking, was a preparation having a certain form, round, four fingers long, and gradually tapering toward the end like the tail of a rat; but, in general, any medicinal preparation, whether solid, liquid, or vaporous, to be applied to the eye or even to other parts (e. g., suppositories were called collyria ani). In modern times collyria are preparations to be applied to the eyes. Solid collyria are usually composed either of solid substances in the crystalline state or in the form of a stick, or of extremely fine powders. Liquid collyria have for base, distilled waters, infusions, or decoctions, to which are added salts or other substances according to the indication. Vaporous collyria are liquids in fine spray, or gaseous substances, for application to the eye.—(Foster).

In the employment of the detergent and antiseptic lotions to the eye attention has been directed to the advisability of warming them to the temperature of the human body. Albrand has invented a small instrument by which the antiseptic liquid can be raised to the desired temperature. A. Duane (Wood's *System of Ophthalmic Therapeutics*, p. 48.) is careful to direct that they should be filtered and tells the patient to examine them from time to time and make sure that no precipitate has formed. If a precipitate does form, the solution is either to be filtered or, better, made up fresh. He is convinced that the precipitation of fine crystals from collyria is often the reason the latter are not well borne.

The term collyrium is also used to include oily solutions whose value is considerable. Merck's *Bericht* says that they have a much more marked effect over aqueous solutions in being less irritant in their action and less liable to decomposition. Panas and Serini (*Repertoire de pharmaçie*, 1898, p. 321.) pointed out these facts some time ago. On the other hand, the preparation of an oily alkaloidal solution requires the greatest possible care, to ensure that it will fulfil its object perfectly. Above all only the free bases, and not the salts of the alkaloids, must be used, as the latter are not soluble in oils. This method is used in the solution of eserine salicylate by warming in olive oil at 150-158° C. Whether this alkaloidal salt will put up with such bad treatment without becoming in part decomposed remains to be demonstrated. The fact is that eserine salicylate is not completely dissolved under these circumstances, or it is in part thrown down again when the mass has become cold. To employ a preparation of this kind in ophthalmic practice appears to be risky, since it is impossible to know how the products of decomposition will behave. It is equally undesirable to attempt to prepare solutions of the sulphate, chloride, etc., of eserine and of other alkaloids by a method of this kind. Whether the oleates and stearates of the alkaloids are suitable for oil collyria is equally open to question; they are certainly soluble in oil, but it is necessary to determine whether the fatty acids are not irritant.

It is thus safest to use the alkaloids themselves which are sufficiently soluble in oil. According to Serini the following solutions are to be recommended for practical purposes:—

Atropine alkaloid 0.2 to 0.5 per cent.; cocaine alkaloid 2 per cent.; duboisine alkaloid 0.2 to 0.5 per cent.; eserine alkaloid 0.5 to 1 per cent.; holocaine 1 per cent.; homatropine alkaloid 0.2 to 0.5 per cent.; pilocarpine alkaloid 2 per cent.

As solvents either olive oil or arachis oil may be used. Serini

removes the free fatty acids from these oils before use by shaking with alcohol, and removing the alcohol by heating to 120° C. A less desirable plan is first to dissolve the alkaloid in ether, to mix this with the oil, and to allow the ether to evaporate.

The finely powdered alkaloid is best rubbed up with a little olive oil; add the remainder of the oil, and gently warm it until solution has occurred. In so doing, the temperature must be regarded to suit the stability of the particular alkaloid, and the temperature must never exceed the melting point of the alkaloid. Thus for pilocarpine, which is liquid at the ordinary temperature, it is sufficient to warm the oil to 40 degrees; for atropine, cocaine, eserine, duboisine and homatropine, a temperature of 50 to 80 degrees C. is required.

B. Zieminski recognizes (*Postep Okulistyczny,* Nov. 12, 1912) the difficulties encountered not only in the sterilization of aqueous solutions of alkaloids employed in ophthalmology, but in their preservation in an aseptic condition. The most important of these are those of cocain and atropin, both of which tend to form flocculi and thready masses which are nothing more or less than colonies of micro-organisms. The repeated shaking of these solutions also has the inconvenience of increasing their concentration, and further, of provoking the decomposition of the alkaloids. The addition of antiseptic substances in sufficient quantity causes irritation of the eye, and when added in a lesser quantity their power is insufficient to arrest pollution by micro-organisms. That is why *oily collyria,* introduced into ocular therapeutics by Panas and his followers, merit a more extended use.

It is true that the preparation of oily collyria requires great care and special measures, but in return they offer real advantages. Moreover, they are singularly stable and keep their transparency for a long time even when in contact with the air. The chemical and bacteriological researches of Panas, Scrini, Terson and others have proven that oily solutions even at the end of several months and without special precaution, do not show bacterial infection. It may even be stated that oily liquids are not propitious to the development of bacteria. Zieminski, after several years' experience, concludes that oil solutions of alkaloids have a more rapid and more energetic action than aqueous solutions.

We may expect the best results from oily solutions of cocain (particularly in traumatic lesions of the cornea) and eserine, which latter does not produce the painful iritic contractions, and never takes on the red color, which in watery solution has been called rubresine.

Collyrium adstringens. (L.) Aqua ophthalmica aluminosa (q. v.), and collyrium adstringens zinci (q. v.).

Collyrium adstringens luteum. (L.) Saffron-yellow astringent collyrium; made by dissolving 25 parts of ammonium chloride and 50 of zinc sulphate in 4,000 of distilled water, adding 15 of camphor mixed with 800 of 70 per cent. alcohol and 4 of saffron, digesting 24 hours with frequent agitation, and then filtering.

Collyrium adstringens zinci. See **Collyrium adstringens luteum.**

Collyrium aluminosum. (L.) Aqua ophthalmica aluminosa (q. v.).

Collyrium antiphlogisticum. (L.) Liquor plumbi subacetatis dilutus.

Collyrium Asclepios. (L.) A collyrium of the ancient "blunderbus" variety, containing opium, sagapenum, opopanax, verdigris, gum, black pepper, calamine and ceruse.

Collyrium astringens luteum. A synonym of collyrium adstringens luteum. See also **Horst's eyewater.**

Collyrium, Benevenuto's. The formula and method of preparation are as follows:—Take an ounce of powdered sugar, an ounce of dried petals of red roses and two pints of ordinary white wine. These should be boiled to one-half and filtered. The resultant liquid is a clear syrupy fluid, rose-color by reflected light and orange-yellow by direct illumination. The collyrium is mostly used in trachoma with abundant secretion, in sub-acute conjunctivitis and phlyctenular conjunctivitis. The secretion and hyperemia in this disease are said to be greatly reduced by this application until a cure is brought about.

Collyrium cæruleum. (L.) Solutio cupri ammoniacalis.

Collyrium cæsarianum. (L.) An ancient collyrium containing atramentum sutoris, white pepper, opium, gum, washed calamine, and antimony.

Collyrium calomelanos. (L.) A dry collyrium containing calomel.

Collyrium canopite. (L.) Another medieval "blunderbus" collyrium, containing cinnamon, acacia, washed calamine, saffron, myrrh, opium, gum, white pepper, frankincense, and copper scale.

Collyrium chiacum. (L.) An old collyrium containing various solid ingredients bruised together in Chian or other wine.

Collyrium excitans. Collyrium exsiccans. Ammoniacal solution of copper.

Collyrium ex hydrargyro muriatico corrosivo. (L.) An eyewater whose principal ingredient is mercuric chloride. The ocular tissues are adversely affected by a stronger (watery) solution than 1:2000 of bichloride. Probably the most desirable antiseptic effects are produced by sublimate irrigating fluids of less strength.

Collyrium exsiccans. Collyrium excitans. Solutio cupri ammoniacalis.

Collyrium Fernandez. (L.) A mixture made by triturating together

1 part of precipitated calomel, 2 parts each of powdered alum and powdered camphor, 24 parts of powdered gum arabic, adding a little water to make a thick paste, stirring in 8 parts of turpentine, and then, little by little, 384 parts of water, straining through linen with expression, and finally mixing with 2 parts of spirits of ether in a well-stoppered bottle. It should be shaken before being used.

Collyrium Gimbernat. (L.) A collyrium made by dissolving 1 part of caustic potash in 288 parts of distilled water.

Collyrium nihili. (L.) Oxide of zinc ointment.

Collyrium of the Benedictines. An eyewater made by dissolving extract of soot in vinegar and adding a small quantity of extract of roses. It was a celebrated and popular remedy for scrofulous ophthalmia.

Collyrium opiatum. (L.) A solution of 1 part of extract of opium in 500 parts of rose-water.

Collyrium phynon. (L.) A collyrium containing saffron, opium, washed copper scale, myrrh, and white pepper.

Collyrium plumbatum. (L.) An eyewater corresponding to the dilute solution of lead acetate (q. v.).

Collyrium pyxinum. (L.) An ancient collyrium containing rock-salt, ammoniacum thymiamatis, opium, ceruse, white pepper, Sicilian saffron, gum, and washed calamine.

Collyrium rhinion. (L.) A "shot-gun" prescription in the form of a collyrium containing myrrh, opium, juice of acacia, pepper, gum, lapis hæmatites, Phrygian stone, lycium, lapis scissilis, and copper scale.

Collyrium sapphiricum. (L.) Solution of ammoniated copper.

Collyrium siccum. (L.) A dry collyrium, as opposed to the liquid collyrium or eyewater.

Collyrium siccum Alexandrinum. (L.) The dry collyrium of King Alexander (q. v.).

Collyrium smilion. (L.) An ancient collyrium containing cinnamon, acacia, washed calamine, saffron, myrrh, opium, gum, white pepper, frankincense, and copper scale.

Collyrium stierncronense. DECOCTUM RUTÆ ZINCATUM. EAU D'ALIBOUR. EAU D'YVEL POUR LES YEUX. A medieval preparation made by boiling 61 parts of rue in 734 of water till reduced one half, adding 30 of zinc sulphate and 11½ of copper sulphate, and, when these are dissolved, 1$\frac{9}{10}$ of camphorated brandy; or by triturating 5 parts of camphor and 2 of saffron with a little water, adding water enough to make 1,227, and 38 each of the sulphates of zinc and copper, and filtering.

Ancient Medicinal Stamps.

Collyrium tephrion. (L.) A medieval collyrium containing starch, gum tragacanth, juice of acacia, gum, opium, washed ceruse, washed spuma argenti, and rain-water.

Collyrium, The, in antiquity. A collyrium meant, throughout antiquity and the middle ages, not a wash, but a cake. Hence the fact that gums of various sorts were always included by ancient and medieval oculists among the ingredients of their collyria. These collyria, or little cakes, resembled tiny bars of soap, were stamped on one or more sides with words or letters serving to indicate the ingredients (generally so numerous as to correspond to what in modern times is designated the "blunderbus" or "shot-gun" prescription)the name of the inventor or prescriber, and the diseases for which the particular collyrium was supposed to be efficacious. Stamps used for this purpose have been recovered in large numbers, especially in western Europe.

For further information concerning ancient collyria and the seals, or stamps, of oculists, see **Celsus** (for ingredients) and **History of ophthalmology** (for the subject generally).—(T. H. S.)

Collyrium zincicum. (L.) A medieval name for unguentum zinci oxidi.

Colmascope. An instrument for detecting evidences of strain in lenses and lens blanks. With the colmascope it is possible to detect mechanical or physical strain in a mounted lens or in a lens blank.

Colmascope.

In the case of mechanical strain due to over-tight mounting this can be relieved by re-mounting, or in many cases by easing up on the glass screw. The colmascope is shown in the accompanying illustration. The lens or lens blank to be tested is held within the recess at the right side of the instrument, the operator sighting through the eye-piece. The light is thrown upward from an electric bulb in the base. A spring push-button is used for turning on the

current. Releasing the button automatically cuts off the light. Where strong direct daylight is available the mirror slide is pushed forward to reflect upward the light which enters the ground glass aperture at the front. When using electric light the mirror slide is drawn back. The electrical attachment is arranged for use with either direct or alternating current of any regular commercial voltage.

The existence of strain in a lens blank is visible by colmascopic examination in the form of well-marked and defined shadows. In some cases these shadows are edged with spectral colors. The greater the strain, the more intense and vivid are the colors.

Coloboma. (L.) A loss of or defect in the tissues, acquired or congenital. The term is particularly applied to a congenital deficiency of or fissure in some portion of the eye.

Although this subject is comprehensively discussed under **Congenital anomalies of the eye,** as well as under special headings, yet there are some considerations common to all of these developmental defects that may be profitably considered here. One of the best articles on the matter, as a whole, is by Beatson Hird (Colobomata of the Eye, *Ophthalmic Review,* June—November, 1912) from which the following account is largely taken. The report he gives is primarily based on 16 patients (exhibiting various forms of coloboma) that he personally examined. He states that in none of his cases was he able to trace any sign of heredity. Although several came of large families none were similarly affected.

He saw the mother whenever possible. In no case had she suffered from any definite intra-uterine inflammation nor had she had any definite disease of a febrile nature during the pregnancy.

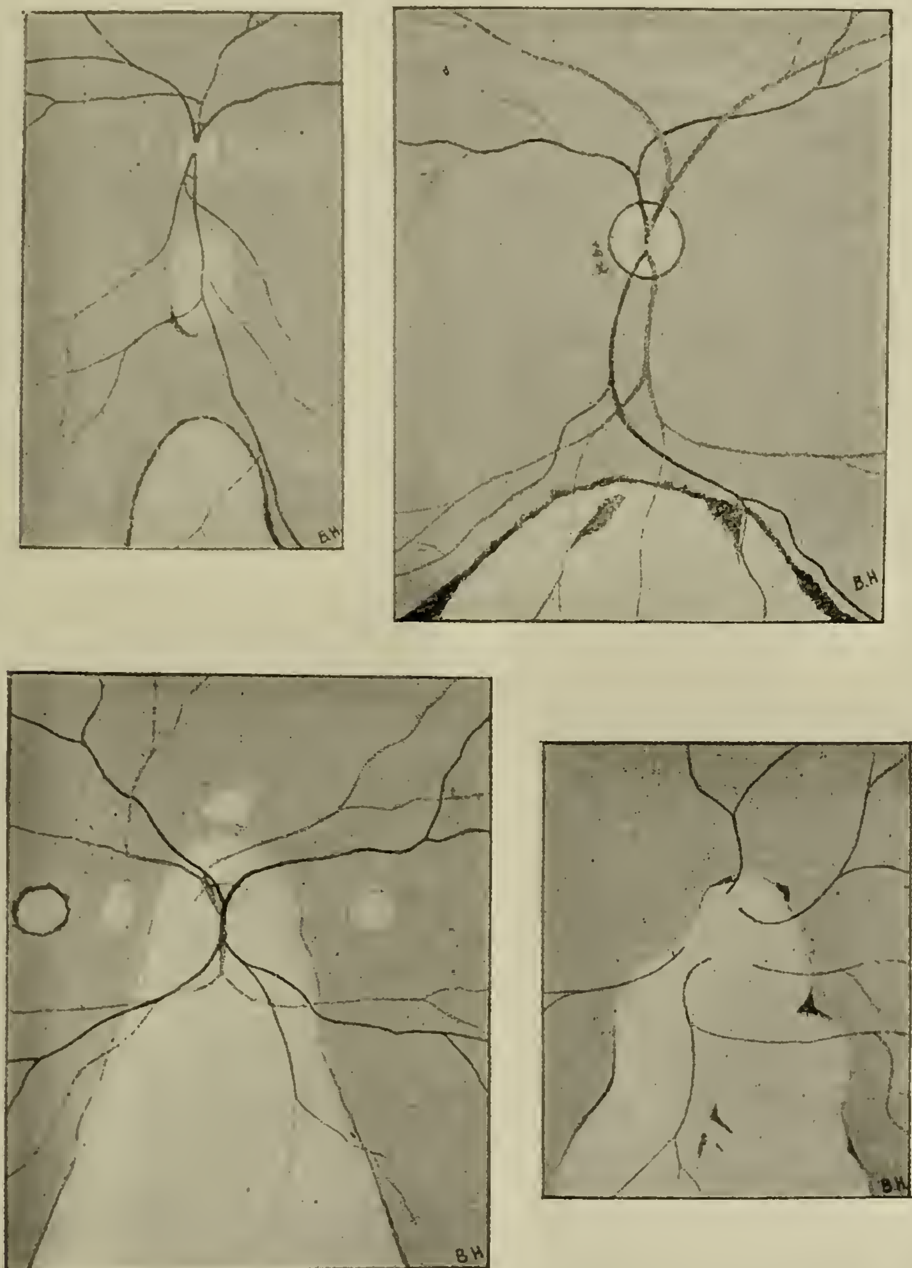
In no case was there any positive evidence of syphilis in either parent or congenital in the colobomatous patient.

In his series of cases 26 eyes were colobomatous and where the *refraction* could be ascertained presented the following varieties of error:—

Simple hypermetropia	2 cases
Hypermetropic astigmatism	8 "
Mixed astigmatism	3 "
Simple myopia	8 "
Myopic astigmatism	2 "

They were evenly divided then between hypermetropia and myopia, and astigmatism only slightly predominated. The visual acuity was, as a rule, defective, in the colobomatous eye. In one case, however, in spite of well marked hypermetropic astigmatism, with correction vis-

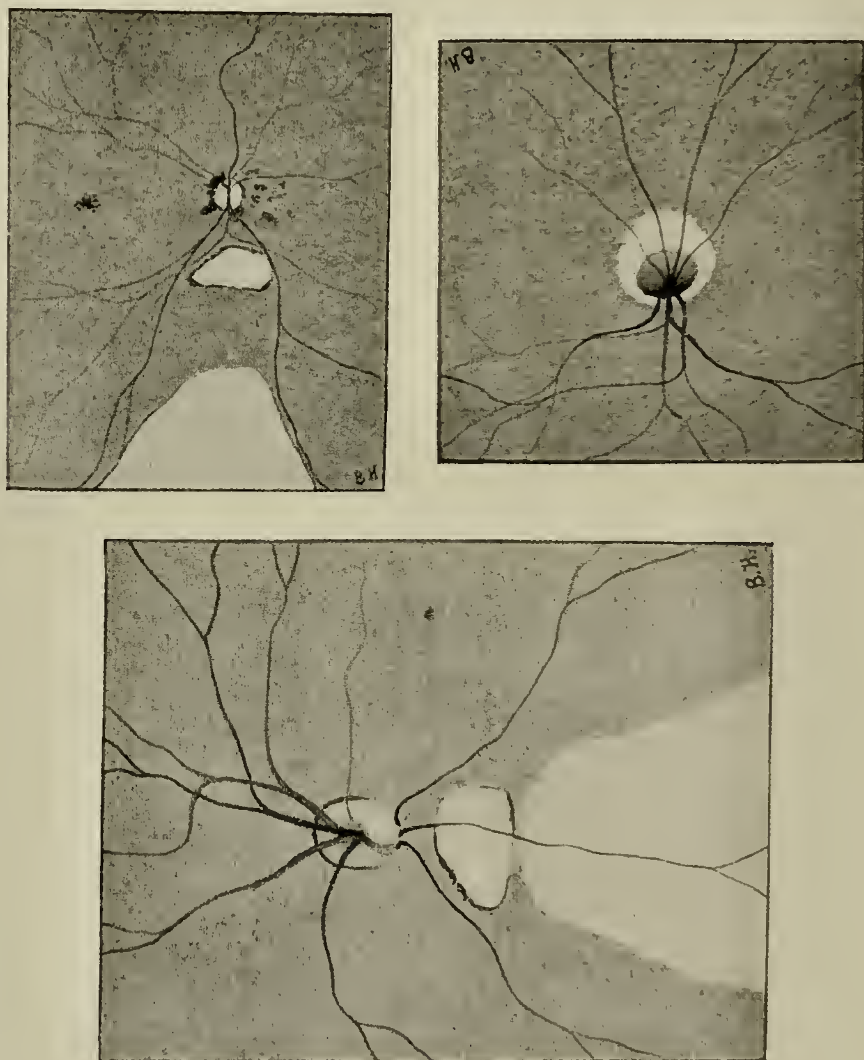
ual acuity was practically normal. In some cases the vision was very bad. Taking an average vision in the rest of the cases it was barely one quarter of normal. It has been suggested that this is often due to abnormal shape of the cornea. A coloboma of the iris alone should not



Colobomata of Choroid, Retina and Optic Nerve. (Hird.)

necessarily affect vision. Colobomata of the choroid are usually associated with defective vision to a varying extent. When the lens is involved, even if there be no opacity, the vision is bad. The worst vision seems to be associated with coloboma of the nerve head and sheaths. Macular colobomata naturally give rise to bad vision.

One would naturally expect the *visual field* to be deficient in those eyes presenting a coloboma of the choroid and retina, as well as those involving the optic nerve. An amblyopic area, corresponding in shape to the coloboma should be present if the retina were absent or too ill-developed to functionate. The fields were taken with a perimeter in 10 cases with the following results:—



Colobomata of the Choroid. (Hird.)

Slight general contraction of the fields in.......... 2 cases
Marked general contraction of the fields in........ 2 cases
Definite notch in field corresponding to coloboma... 3 cases
Contraction of the field corresponding to coloboma.. 1 case
Field full and normal........................... 2 cases

In none of the cases where there was an amblyopic area corresponding to the coloboma did it appear to be as extensive. Parsons quotes

various authorities on the fields in colobomata. Schmidt-Rimpler proved that even when a defect was present there was generally light perception in the defective area, and Haab showed perception of red and blue. Benson demonstrated constriction of the field at the periphery without any scotoma. In macular colobomata a defect in the field may be absent or impossible to determine. Absolute scotoma has been noted by several. A ring scotoma has also been reported and relative scotoma is common.

Of 119 cases reported in literature the following was the *frequency of occurrence:*—

Coloboma of the iris	82 occurrences
Coloboma of the choroid	24 occurrences
Coloboma at the nerve entrance	34 occurrences
Coloboma of the lens	22 occurrences
Coloboma at the macula	6 occurrences

In the 26 eyes affected in Hird's series the result was as follows:—

Coloboma of the iris	22 occurrences
Coloboma of the choroid	20 occurrences
Coloboma at the nerve entrance	10 occurrences
Coloboma of the lens	8 occurrences
Coloboma at the macula	1 occurrence

In many of his cases several varieties occurred in the same eye.

It has been stated that the left eye is more frequently colobomatous, but from these cases this does not appear to be so.

Many authorities have reported the presence of *other developmental defects* in cases of ocular colobomata. The following have been reported:—persistent pupillary membrane; abnormalities in shape, size, and curvature of the cornea; opacities in the lens; strabismus; nystagmus; coloboma of lid; hare-lip; epibulbar dermoid; microphthalmos; persistent hyaloid artery; opaque nerve fibres; and anomalies of the head, trunk and limbs. With regard to Hird's cases the following conditions were present:—

Nystagmus in 2 cases.

Convergent strabismus in 2 cases.

Microphthalmos in 1 case.

Absence of the right external ear and hemiatrophy of the right face, 1 case.

Opacities in the lens in 2 cases.

In no case were any remains of the pupillary membrane to be seen.

As to the *prognosis* in colobomatous cases, there is sufficient evidence to show that these eyes are more liable to inflammations and disease. In one case where syphilis was acquired, the colobomatous eye was the

one that suffered. From the fact that these eyes are liable to inflammation they are unsuitable ones to operate on (De Beck).

Etiology. There appears to be no marked incidence of colobomata in either sex. In 119 cases the sex was given in 78 only, and of these 35 were males and 43 were females. In the writer's 16 cases 8 were males and 8 were females. Quite a number of cases have been reported occurring in families of which three well marked examples are given by Streatfield, De Beck, and Snell. In each of these the condition was traced through several generations. Other cases are recorded.

Heredity undoubtedly plays an important part in the condition, but this is not necessarily the case. Treacher Collins, in discussing the primary cause of ocular abnormalities, states that he found in twelve cases some *mental impression or fright* was said to have occurred during pregnancy. In six cases it occurred during the first month and may therefore, he thinks, be reasonably regarded as a disturbing agent. In four of Hird's cases he obtained a history of maternal fright. In each case it was given as an explanation of the child's defect, and this too without asking any direct question on the matter. There are some who believe in the influence of maternal impressions on the development of the body. The eye begins to develop at an early period of fetal life and is visible at the beginning of the fifth week, so that, as has been mentioned above, any impression that is to affect its development should be received during the first few weeks of pregnancy; at the very time indeed when the mother is probably unsuspicious of her condition. In most of my cases the fright was at a later date than this. Hird cannot understand how a mental process in the mother can affect the developing fetus, and believes that the cases are either coincidences or fabrications on the part of the mother.

The *pathology* of ocular colobomata has been most ably stated by Parsons. The main theory brought forwards is one of maldevelopment. It is supposed that the fetal cleft fails to close properly, and such a view is supported by the fact that the majority of colobomata occur at the site of this cleft. But there are obstacles to this in the form of atypical colobomata, a few instances of which occurred among my cases and will be mentioned later. As a rule the cleft involves the lower and inner part of the optic vesicle, and this is the common site of the ocular colobomata where indeed all the structures of the eyeball may be involved. The theory supposes that there is some defect in the closure of this fetal cleft and the mesoblast, that should give rise to the choroid and sclera here, develops in an abnormal manner. This seems a very convincing and acceptable argument, but we have the atypical cases to explain. Van Duyse has expressed the opin-

ion that the abnormal persistence of the pedicle of the mesoblastic intrusion prevents the normal closure of the optic fissure; this is finally filled in by a mass of "intercalary" connective tissue, which takes the place of the sclerotic, but behaves in effect like cicatricial tissue. Its contraction causes the dragging out of place of the iris and ciliary processes, its compression of the vessels piercing it causes local irritation, edema, and inflammation, and leads to softening and ectasia of the scleral tissue as well as inflammatory appearances about its margins. The primary cause of the coloboma he would trace to a defect in the evolution of the encephalon or its coverings.

Benson has recorded an interesting case of which the following were the chief points. In the left eye there was a coloboma of the nerve sheath but none of the choroid or iris, and in the position of the junction of the lips of the choroidal fissure, disturbance in the pigment layer suggesting the idea of a raphé. Here we have a condition that had just missed being a coloboma of the choroid, and it is particularly interesting as there is a permanent trace in birds according to Hulke.

When only portions of the fetal cleft fail to close and so develop abnormally then the coloboma is limited to this position.

Parsons says that if we grant that the colobomata are due to arrested or defective closure of the fetal cleft, there still remains the question of the mechanism whereby this is brought about and the following theories have been advanced.

(1) The mesoblastic theory, that the seat of the mischief is in the mesoblast whether consisting of over- or under-development.

(2) The retinal theory, that the primary seat is in the retina, which proliferates unduly.

(3) The lenticular theory, that closure is prevented by relative abnormal development of the lens as compared with the size of the eye.

What explanation have we for the atypical colobomata, viz., those abnormally situated, when regarded from the point of view of maldevelopment? We are indebted to v. Ammon, who discovered an atypical subsidiary fetal cleft in animals. Others have confirmed this including Van Duyse, who has described a double fetal cleft in a calf embryo. Four of Hird's cases may be included in the category of atypical colobomata. In one case there was a double coloboma of the iris, or perhaps partial aniridia is a better term.

Coloboma of the iris is by far the commonest and usually situated downwards and inwards giving rise to a key-hole or pear-shaped pupil. The pigmented posterior layer of the iris is the most anterior portion of the retina and consists of the two applied layers of the optic

vesicle. The stroma of the iris is developed from a forward growth of the mesoblast that has given rise to the choroid and ciliary bodies. It lies immediately behind and adjacent to the thin layer of mesoblast which bounds the primitive anterior chamber posteriorly and forms the pupillary membrane. Anything then that could interfere with this forward growth of the iris might give rise to a gap and the condition of coloboma. Delayed closure of the fetal cleft might be such a factor. If the iris did not develop at all then a complete coloboma would result. If the iris was delayed in growing forward and so only partly developed then a partial coloboma would be present. If the fetal cleft has closed anteriorly early and normally then the iris will develop properly and so a coloboma of the choroid would result with a normal pupil.

Treacher Collins has given an excellent explanation of iris coloboma as follows:—"Before the iris is formed in the fetus there exists, between the posterior surface of the cornea and the anterior capsule of the lens, the anterior portion of the fibro-vascular sheath. This receives its blood supply partly from the ciliary arteries and partly from those in the posterior fibro-vascular sheath prolonged round the sides of the lens to join it. The cornea, anterior fibro-vascular sheath and lens lie in close contact with each other. The iris is developed by growing forwards from the margin of the anterior chamber, and in doing so has to insinuate itself between the cornea and anterior fibro-vascular sheath on the one side and the lens on the other, pushing the prolongation from the posterior fibro-vascular sheath in front of it. The anterior fibro-vascular sheath subsequently becomes the pupillary membrane, of which portions sometimes persist. If we suppose some abnormal adhesion to occur between the cornea, anterior fibro-vascular sheath, and lens capsule, or some delay in their separation, at the whole circumference of the future anterior chamber, we can understand how a mechanical obstruction to any growth of the iris forwards would be introduced, resulting in complete absence of iris or irideremia. If the obstruction be confined to a position only of the anterior chamber, the corresponding portion only of the iris will be prevented from growing forwards, and the result will be one or more congenital colobomata."

This would explain colobomata of the iris when situated upwards or outwards and would explain also double coloboma.

Other theories have been brought forward to explain atypical cases.

Pflüger upholds the theory that the eye undergoes rotation, but this does not explain double coloboma. Makrocki advocate an abnormally placed choroidal fissure.

Plange suggests abnormalities in the absorption of the pupillary membrane having something to do with this, but Bock observes that the two conditions rarely coexist.

Abnormally placed colobomata are rare but nevertheless quite a number have been reported, i. e.,—outwards 16; inwards 11; upwards and outwards 11; upwards and inwards 6; upwards 7; downwards and outwards 3.

Coloboma of the iris with a bridge is due to some remains of the pupillary membrane extending across the coloboma. Treacher Collins explains this condition as due to failure in development of one of the loops of blood vessels which bud off from the anterior ciliary arteries at the ciliary margin. These anterior ciliary arteries anastomose with vessels from the central hyaloid artery, from the posterior fibro-vascular sheath of the lens, which extend forwards round the sides of that structure and in front of the pupillary margin of the developing iris. If a loop fails to develop from the anterior ciliary arteries, the vessels from the central hyaloid being normal, then a gap would occur in the iris periphery bridged across by tissue where the circle of anastomosis had taken place.

Coats, in describing the abnormalities in a case of microphthalmos, gives details of a mesoblastic strand that persisted and was inserted into the sclero-corneal junction giving rise to a grip in the iris and ciliary body. He points out that failure of differentiation in the anterior part of the eye does not result in the fusion of a fully developed iris with the cornea but in the fusion of the pupillary membrane with the cornea. This prevents the iris, developed at a later date, from growing in. That whereas anterior synechiæ of the pupillary membrane may be due to perforation of a corneal ulcer his case shows that it may also certainly be a pure malformation.

In discussing theories of causation of coloboma and aniridia Coats says the only ones worthy of consideration are those which presume an obstacle to the ingrowth of the iris from the periphery which normally occurs at the fourth month. Four hypotheses have to be considered in this connection. They are as follows:—(1) The hypothesis of Manz assumes that the lens remains unduly long in contact with the cornea while the eye is developing and so hinders the iris from growing in. In double coloboma of the iris this would have to take place in two spots, a point difficult to comprehend. (2) That the mesoblast fails to separate properly into cornea and iris, so that the iris is never differentiated and cannot grow inwards. (3) The hypothesis of Treacher Collins assumes that the fibro-vascular sheath remains adherent to the anterior lens capsule and so prevents the

ingrowth of the iris. (4) Hess suggests that in normal circumstances the mesoblast of the fibro-vascular sheath passes round the anterior edge of the secondary optic vesicle and becomes continuous with the mesoblast from which the iris is to develop, and from which the pupillary membrane springs. Should this tissue, or a strand of it connected with some particular vessel, be unusually dense and unyielding, both the optic vesicle and the mesoblast which should form the iris will be prevented from growing inwards, and aniridia or a coloboma will result. It is not mere persistence of the mesoblast which prevents the ingrowth of the iris, since even normally it persists till late in fetal life; but in ordinary development it yields to the growing iris and follows it inwards over the lens.

Coats' researches strongly support Hess's theory and he declares himself in its favor. As he says, Hess's theory explains well the atypical colobomata of the iris, brings a large number of abnormalities under one common explanation, and explains their association with one another. The same explanation holds good for aniridia, partial aniridia, coloboma, and atypical coloboma.

Coloboma of the iris has been examined microscopically, and Parsons reports that the "edges are normal in thickness in the upper part but much thickened and nodular in the lower. As observed clinically, the retinal pigment epithelium is over-developed at the margins, often projecting beyond them. The sphincter may be absent, or may spread out and be lost. Abnormally profuse development of vessels may be seen in the lower part, as well as nodular aggregations of round cells. Sections of a raphé in partial coloboma show triangular depression of the surface, with projection or depression of the posterior surface."

Coloboma of the ciliary body was not noticed in any of Hird's cases, although he would not say that there was no abnormality of the ciliary body in any of them.

The ciliary body has been shown to take part in the abnormality, and seeing that the iris and ciliary are both developed from the same mass of mesoblast, this is not to be wondered at.

Coloboma of the choroid and retina must be considered together, owing to the intimate way in which they are associated. This condition is commonly present with coloboma of the iris, but may occur alone and may vary in size and shape. It may involve the disc and extend towards the periphery in an ever-widening area until it is lost in the region of the ciliary processes, or there may be present, in the line of the fetal cleft, an oval area in the midst of apparently normal tissue. They can all be explained if it be considered that the

defect is due to an abnormal adhesion of the retina to the mesoblast, so that when this adhesion takes place before the retinal fissure is closed, the coloboma is devoid of a covering of retina, and an absolute scotoma exists, whereas when it occurs after the closure of the fissure, the retina is everywhere present, and there is no scotoma.

Macular colobomata are usually horizontally oval with sharply defined pigmented margins, and blood vessels from the retinal or ciliary arteries may be present. They are often bilateral and ectactic, and myopia is a frequent occurrence.

Coats calls our attention to two points in coloboma of the optic nerve entrance; (a) the relation of the intervaginal space to the ectasia. A coloboma of the nerve will show an ectasia related to the inner or pial portion, whereas coloboma of the choroid will present an ectasia related to the outer or dural portion. (b) Absence of central vessels or atypical development. This does not mean that there is a coloboma of the nerve, for the cleft may have closed properly and the nerve be normal, the blood vessels being left out. On the other hand, the presence of vessels in the nerve does not exclude coloboma, as the cleft may have failed to close.

As he says, it is really impossible to draw any hard and fast distinction between coloboma of the nerve and coloboma of the adjacent choroid, and indeed the two occur in combination. He divides the cases into three groups, as follows. 1. Those in which the lesion is a coloboma of the choroid beneath the nerve, the nerve itself being normal and only sharing passively in the deformity. 2. Those in which the lesion is a coloboma of the choroid and nerve. 3. Those in which the lesion is a coloboma of the nerve alone, the adjacent choroid being normal.

The appearances of coloboma at the optic disc may vary considerably. Usually there is enlargement of the disc and its typical character may be entirely lost, as was the case in some of my examples. The surface of the coloboma is generally white, and there may be partial or total ectasia of the surface.

Caspar has divided the arrangement of the vessels into three groups: 1. All the vessels emerge from the lower part of the pseudodisc, even those which subsequently turn upwards. 2. They emerge at or a little above the center and are nearly normally arranged. 3. The vessels appear at the edges around the whole circumference.

Hird has had no experience of *coloboma of the vitreous,* although some cases have been reported in which there were indentations in the lower part of this body, the cleft being filled with vascular connective tissue.

Coloboma of the lens consists of an irregularity of the border, and this, when not marked, can only be seen when the pupil is fully dilated; consequently there must be quite a number of cases, of the slighter type at any rate, that go undetected. Various explanations have been given of coloboma of the lens, such as deficiency in nutrition from maldevelopment of the vascular sheath; absence of the suspensory ligament at the site of the coloboma, which in consequence did not exert any traction on the developing lens. The most important is Hess's view, that the vessels in the vascular sheath persisted too long and so prevented the growth of the lens locally, by pressure. This is made possible by the fact that the vascular sheath does not disappear until late in fetal life.

Hird gives as his personal views that colobomata of the eye are due to faulty development, and advances the following arguments in support of this: 1. There is no doubt that heredity plays an important part. Nothing more need be said, after the tables produced. Is it likely that a condition, handed down from generation to generation and always affecting an eye in a similar manner, is due to an inflammatory origin? von Hippel's experiments support this, for he was able to breed rabbits from a colobomatous parent and obtained the defect in twenty-three out of one hundred and twelve eyes. Microscopic investigation entirely favored the theory of maldevelopment. There were no signs of any inflammatory condition. 2. The microscopic evidence, as just stated and quoted above, does not support the theory of inflammation. 3. Coloboma of the lens does not appear to offer any reasonable explanation from an inflammatory point of view. 4. The presence of other congenital defects so often found in these cases strengthens the supposition that they too owe their origin to an error of development.

Coloboma, Bridge. A variety of iridic defect in which the pupil is separated from the coloboma by a thread of iris-tissue. This marginal strand stretches like a narrow bridge from one pillar of the coloboma to the other. See **Congenital anomalies of the eye.**

Coloboma bulbi. (L.) Coloboma of the eyeball.

Coloboma choroideæ. (L.) Coloboma choroidis. A defect of development in the chorioid, which usually involves its entire thickness. It is generally associated with coloboma of the iris and ciliary body, though it may exist alone. Although it may affect any part of the choroid it is usually found in the line of the fetal fissure. See **Congenital anomalies of the eye.**

Coloboma della lente. (It.) Coloboma of the crystalline lens.

Coloboma dell' occhio. (It.) Coloboma of the eyeball.

Coloboma del nervo ottico. (It.) Coloboma of the optic nerve.

Coloboma, Extrapapillary. This is a name suggested by Lindsay Johnson to designate congenital defects in the choroid, which do not involve the disc.

Coloboma, Fuchs. This is a variation in the normal or practically normal scleral ring and is usually seen in otherwise perfectly healthy eyes as a white ring surrounding the nerve-head.

A. S. Worton has investigated (*The Ophthalmoscope*, Dec., 1911) 30 cases of this form of congenital (inferior) crescent.

It has been thought that the gray or white crescent present below the disc really represents a minimal type of coloboma of the choroid. Elschnig, however, from anatomic and microscopic examination of three cases, found appearances practically indistinguishable from those seen in myopia, and regards them as produced much in the same way, viz., by stretching of the ocular tunics at the posterior pole and consequent pulling away of the choroid from the disc margin. This stretching he ascribes to some developmental weakness or want of consolidation of the tissues in the line of the fetal cleft, which permits of their giving away before the normal intraocular tension.

The macular area, although not directly involved in this stretching, may yet secondarily be affected from proximity to the weakened region below, and a condition of asymmetry may develop to which the term "fundal astigmatism" has been applied.

This macular distortion in typical cases doubtless accounts for the well-known fact that the visual acuity, despite correction, remains considerably below normal, although, on the other hand, it must be noted that in the less marked cases at least, as will be seen from those reported later, the condition is not incompatible with practically full vision.

Astigmatism was found to be present in greater or smaller degree in all the eyes affected, and in the large majority (63.6 per cent.) was made up of combined corneal and lental astigmatism. In some (22.7 per cent.) the astigmatism seemed to be wholly corneal, and in the remainder (13.6 per cent.) wholly lental in character.

In those cases where both corneal and lental astigmatism coexisted in the same eye, the axes were found to be practically coincident, this probably pointing to a common source of origin. A careful comparison of the tabulated result shows a remarkable correspondence between the meridian of greater refraction, i. e., the more myopic or less hypermetropic, and the direction of fundal stretching.

In 63.6 per cent. of the eyes affected, the direction of fundus stretching corresponds to a meridian of 110 and 90 in the right eye, and

between 70 and 90 in the left, representing the usual direction of the fetal ocular cleft. The crescent may, however, be shifted in some cases, and occupy a nearly nasal position, and in one case the crescents were bilateral and superiorly situated.

Ophthalmoscopically, the disc proper in a typical case appears to be oval horizontally, because seen foreshortened in the horizontal plane; the white or gray crescent apparently forming part of the disc area, is yet limited from it by a line representing the exposed margin of the sclerotic, which also encroaches to a greater or less extent on the fundus below.

The primary direction of the vessels is downward, the lower branches continuing thus, but the upper soon curve sharply upwards over the disc margin to gain the fundus. A very constant feature of all is the bleached or semialbinotic state of the fundus in its lower and inner part. This was observed in all cases, and probably owes its origin to some lack of pigmentation in the layer of hexagonal epithelium of the retina and attenuation of the choroid due to stretching.

Over this area some impairment of retinal function may be elicited in response to color tests. In five cases presented there was a flattening of the upper fields for green. A somewhat similar bleaching of the lower part of the fundus is often observed in cases where the rest of the fundus and discs remain otherwise normal. These cases are very often associated with astigmatism and probably represent a minor degree of the condition under discussion.

The correspondence observed between the axis of the meridian of greater refraction and the direction of fundal stretching would seem to justify the conclusion that they were closely related as to cause, and possibly throws light on the etiology of simple corneal astigmatism, which similarly may owe its origin to some stretching of the tissues filling up the anterior part of the fetal ocular cleft. (Abstract *Annals of Ophthal.*, April, 1912). See, also, **Fuchs' coloboma.**

Coloboma incompletum. (L.) Bridge coloboma.

Coloboma, Iris. A fissure in the iris, of varying size and shape, due to arrest of development. It may affect one or both eyes and is usually accompanied by a coloboma of the ciliary body and choroid. The fissure is triangular or pyriform in shape, with the base toward the pupil and the apex toward the periphery, though it may not extend quite to the periphery. (Foster.)

Although this subject is fully discussed under **Congenital anomalies of the eye,** a reference may here be made to a rare form of the defect, reported by Purtscher, *a congenital coloboma upwards.* It occurred in the left eye in a boy, aged 4 years, who also had a

fissure at the site of the lower punctum. Behind this on the lid border there was a fleshy prominence resembling a second caruncle, ectasia and blennorrhea of the lachrymal sac, and a very fine fistula in the upper lip below the insertion of the left nasal wing. V.=3/30; the normal right eye 3/5. The coloboma was *directly upwards*. The small and large circles of the iris were well differentiated and could be clearly discerned along the coloboma. The writer explains the

Colobomata of the Iris. (R. B. Hird, *Oph. Review*, June, 1912.)

atypical coloboma by an arrest of development by persisting mesodermal bands.

As shown in this patient, and as is commonly the case, congenital ocular defects are generally associated with others, not, however, necessarily of the eye structures.

Simeon Snell (*Oph. Review*, Mar., 1908) showed a family tree in which 12 members (5 male and 7 female) out of a total of 41, extending over five generations, exhibited a coloboma of the iris. The defect was the same in all cases, viz., downwards and outwards, confined to

the iris, and the choroid not being affected, and situated quite peripherally so that the edge of the lens was visible. A patient who came under Snell's observation, and whose mother had been affected, had children by two husbands, and in both branches of the family there were found members who had the same deformity; and it is also remarkable that the only two affected members of the younger generation were females, and the subjects of complete aniridia. See, also, **Congenital anomalies of the eye.**

Coloboma lentis. A congenital defect in the crystalline lens system, usually occurring at the lower margin of the lens and including the corresponding fibres of the zonula of Zinn.

This subject is fully treated under **Congenital anomalies of the eye.** Under this sub-title it may be said that *congenital defects of the lens* are usually associated with other ocular malformations, as shown in a case reported by Van der Hoeve (*Archiv für Augenheilk.*, Aug., 1912, p. 145) who examined the eyes of a man, aged 19, for military service. V. 2/60, was poor since infancy. One-fifth of the right lens at the nasal side was lacking. The lens border was not convex, as in dislocation, but showed a saddle-shaped indentation. The corresponding pupillary area was jet black, while the remaining portion of the lens gave a bluish-grey reflex. With a strong convex glass behind the mirror the fibres of the zonula Zinnii could be seen in the upper and lower portions of the coloboma, but were missing in the middle portion. The optic disc showed a conus downwards and inwards. The inverted image appeared larger through the aphakic, smaller through the lenticular, part of the pupil. The accommodation of the right eye was diminished.

The majority of colobomas of the lens occur in the lower portion, and such a large atypical coloboma as in this case is rarely observed.

With regard to etiology the experiments of Wessely strongly support the theory of Becker, who attributes the cause of coloboma of the lens to local insufficiency of the zonula. Not all authors ascribe the deformity of the lens to a lack in traction by the zonula, since it has not been decided whether the condition consists in a change of form or a defect. To decide the matter the author compared the weight of the two lenses of rabbits, on one of whose eyes iridectomy had been performed according to the plan of Wessely. The result was that the weight of the lens in the iridectomized eye was less than that of the other. He assumes in this case a poor primary development of the lens or the zonula as the chief etiological element.

Coloboma lentis et corporis vitrei. (L.) A fissure of the lens and vitreous body, the result of arrest of closure of the fetal ocular fissure.

which may extend more or less into the substance of the lens. It may be either unilocular or binocular, and may exist with or without coloboma of other tissues of the eye. (Foster.)

Coloboma, Macular. Coloboma maculæ luteæ. Coloboma at the macular region. Cases of this kind are rare and are not always understood, having been mistaken for choroidal changes. Fischer describes a case—in a girl of 15 who developed convergent squint at the age of three weeks. No other member of her family had eye defects. Ophthalmoscopically there was a spot in the macular region of about five times the size of the disc. Its edges were surrounded by pigment, the interior of this defective area was mottled with yellow and brown pigment, while unpigmented areas had a pearly, glistening white color. The refraction of the defective area was myopic from 0.75 to 3 D. The whole area seemed to be lined by a clear veil, into which the retinal vessels were continued. The other eye contained a similar defective area below the macular region. See **Congenital anomalies of the eye.**

Coloboma nervi optici. (L.) A fissure of the sheath of the optic nerve, rarely affecting the nerve tissue itself, due to imperfect development of the organ. See **Congenital anomalies of the eye.**

Coloboma oculi. (L.) Coloboma of the eyeball. A developmental defect affecting all the coats of the eyeball, including, also, the vitreous, lens, or optic disc, according to its location.

Coloboma of the choroid. A defect in the choroid, almost always a developmental anomaly, fully described under **Congenital anomalies of the eye.**

Coloboma of the cornea. See **Congenital anomalies of the eye.**

Coloboma of the eyelid. Coloboma palpebræ. Coloboma palpebrarum. A rare, congenital defect in which there is a fissure of the eyelid, usually triangular in shape with the base at the palpebral margin and the apex upward or downward. The fissure may vary in width and length, and is seen in either lid, though it is usually met with in the upper lid. It involves the entire thickness of the lid, and the edges are rounded off.

This matter is completely treated under the caption **Congenital anomalies of the eye.** It will suffice to draw the reader's attention to a report by W. C. Posey (*Ophthalmic Record*, April, 1907) of an instance in a girl, ten years of age. There was a congenital absence of a portion of the upper eyelid of the left eye, so that, when the eyes were directed straight forward, the cleft just corresponded to the size and shape of the upper third of the cornea. The eyelid was in no other way deformed except for a small yellowish thickening in the

skin, just above the coloboma, which resembled xanthelasma. The eyeball was normal, except for an anomalous formation of Tenon's capsule at the outer angle of the eye. The bulbar conjunctiva covered this mass, which was grayish-white in color and everywhere smooth and flat. When the eye was rotated inward and separated, the anomaly assumed a cylindrical, sausage-like form and was readily movable over the globe. Both eyes were quite hypermetropic. Vision equally 5/10 in each.

Coloboma of the iris. See **Coloboma, Iris**; and **Congenital anomalies of the eye.**

Coloboma of the lens. See **Coloboma lentis**; and **Congenital anomalies of the eye.**

Coloboma of the lid. See **Congenital anomalies of the eye.**

Coloboma of the macula. See **Coloboma, Macular.**

Coloboma of the optic nerve. See **Coloboma nervi optici.**

Coloboma of the retina. Coloboma retinæ (q. v.). See **Congenital anomalies of the eye.**

Coloboma of the sheath of the optic nerve. See **Congenital anomalies of the eye.**

Coloboma of the vitreous humor. See **Congenital anomalies of the eye.**

Coloboma palpebræ. See **Coloboma of the eyelid.**

Coloboma retinæ. (L.) Retinal coloboma. A congenital defect in the retina corresponding in situation to the fetal fissure of the eyeball. It is always associated with coloboma of the choroid and often with coloboma of the iris. See **Congenital anomalies of the eye.**

Coloboma superficiale. (L.) Bridge coloboma.

Colobom des Auges. (G.) Coloboma oculi. Coloboma of the eyecoats.

Colobome à bride. (F.) Bridge coloboma.

Colobome de l'oeil. (F.) Coloboma of the eye.

Colobome du cristallin. (F.) Coloboma of the lens.

Colocynth, Oculotoxic symptoms of. There is but one reference that I have been able to find to eye symptoms from this powerful purgative. Lewin and Guillery (Vol. 2, p. 953) report that a patient after taking 12 grams of the dried fruit was seized with serious systemic disturbances of the nervous system and digestive tract, and suffered from marked vertigo, dullness of hearing and loss of vision. As the patient recovered, all the symptoms, including the amblyopia, slowly disappeared.

It is believed that Morrison's pills, a proprietary remedy—an overdose of which has been responsible for a temporary amblyopia—con-

tains, among other ingredients, powdered colocynth, and that the eye symptoms set up by poisoning from this remedy may be in part due to this powerful drug.

Colombier, Jean C. An eighteenth century French military physician, hygienist, and ophthalmologist. Born at Toul Sept. 2, 1736. As the son of a surgeon-major, he received his military-medical training at the military hospital in Metz. In 1765 he was graduated with the rank of surgeon-major.

His most important writings are: "*Code de Médecine militaire pour le Service de Terre,*" etc. (4 vols. Paris, 1772), and "*Médecine Militaire, ou Traité des Maladies,*" etc. (7 vols., Paris, 1778). The latter work was written at the command of the French Government.

Colombier wrote almost nothing about the eye, but he was famous as a cataract-extractor. His method of extraction was to make an incision with a lance through the lower portion of the corneal margin, and then, with Daviel's scissors, to enlarge this so as to form a triangular corneal flap. He was one of the first to prefer extraction to couchement, but he declared that the latter operation should always be performed when the cataract was particularly large.

He died Aug. 4, 1789.—(T. H. S.)

Colomiatti, Bacillus of. See **Bacillus of Colomiatti.**

Colon bacillus. See **Bacillus coli communis,** and **Bacteriology of the eye.**

Colonial spirits. The improper employment of the poisonous Columbian spirits (deodorized wood alcohol) as a solvent in the manufactures has indirectly led to blindness through their ingestion and absorption into the system. To aid in this fraud an imitation of the trade form of grain alcohol used in preparing eau de cologne and other perfumes—commonly called cologne spirits—has been placed on sale and called colonial spirits. The similarity of the names needs no comment.

In the *Ophthalmic Record,* Vol. x, p. 342, is reported a case of loss of eyesight from drinking this lethal preparation. See **Toxic amblyopia, Methyl alcohol, Columbian spirits** and **Conservation of vision.**

Color adaptation. On entering a dark room there is a decided change in the degree and quality of color perception, and this alteration occurs immediately and increases with the length of stay and the degree of darkness. There is also a considerable effect produced when a person enters a room illuminated by an artificial light, having previously been in daylight. This change is called color-adaptation, and increases with the time during which the eyes are subjected to the adapting light.

After a series of experiments in color adaptation, Edridge-Green comes to the following conclusions:

1. In color-adaptation, the retino-cerebral apparatus appears to become less and less sensitive to the color corresponding to the dominant wave-length, and to set up a new system of differentiation.

2. When light of a composition differing from that of daylight is employed to illuminate objects, an immediate and unconscious estimation of the colors of these objects is made in relation to this light, the light employed being considered as white light.

3. No color is seen of which the physical basis is not present in the light employed.

4. When spectral regions are examined with a color-adapted eye, that of the dominant wave-length appears colorless, whilst those immediately on either side of it appear to be shifted higher and lower in the scale respectively.

5. There is immediate color-adaptation as well as color-adaptation after a longer stimulation with the adapting light.

6. Colors which correspond to the dominant wave-lengths of an artificial light are with difficulty discriminated from white by this light.

7. Color-adaptation may bring two colors below the threshold of discrimination, so that the two appear exactly alike, although by another kind of light a difference is plainly seen.

8. Color-adaptation increases the perception of relative difference for colors other than the dominant.

9. The conscious judgment has very little effect in color-adaptation.

10. Color-adaptation greatly helps in the discrimination of colors and masks the effects of the very great physical differences which are found in different kinds of illumination.

11. Spectral yellow, after color-adaptation to green, still appears yellow and not red.

12. Color-adaptation appears to produce its effects by subtraction of the dominant color sensation, and not by directly increasing the complementary. Spectral blue does not appear brighter after color-adaptation to yellow.

Colorant. (F.) Coloring.

Colorate. Tinged with color.

Colorational. Dependent on or pertaining to color.

Coloration of the conjunctiva. Staining of the conjunctiva is most commonly due to the various salts of silver—especially to the nitrate and to argyrol—when it is called *argyrosis.* This subject has already been discussed on page 574, Vol. 1, of this *Encyclopedia.*

The long-continued use of iron sulphate has been known to bring about a yellow coloration of the conjunctiva—*siderosis conjunctivæ*. It may be added, in passing, that the brownish spots often noticed on the conjunctiva of the negro are, as a rule, congenital and due to pigmentary deposits; they become more marked in some inflammatory diseases of the eye, acute conjunctivitis, for example. See also **Conjunctiva, Argyriasis of the.**

Coloration of the human lens. This interesting subject has been fully treated by the reviewer (*Ophthalmic Review,* Feb., 1910) of an article by von Hess (*Archiv f. Augenheilk.,* lxiii, 2, p. 164).

It is well known that the lens has frequently a yellow tint, and in advanced life a yellowish-red tint, sometimes of considerable intensity. It has been surmised that the relative perception of certain colors is modified thereby, and some have asserted that this influence is manifest in the pictures painted by certain artists late in life. Hering, examining lenses removed after death, demonstrated an absorption of violet, blue and blue-green rays, increasing with age. Helmholtz regarded the color of the lens as negligible in relation to color perception in healthy eyes. Proof of its influence has hitherto been wanting. Hess has not supplied it. In a previous article he showed that the coloration of the lens may reach such a degree as to involve blue-blindness, although visible opacity and defect of ordinary vision are absent. He now describes a subjective method by which the effect of the lens-color in the living eye can be accurately measured, and an objective method by which the color can be rendered manifest.

To an eye well-adapted for darkness, all colored light, when of sufficiently low intensity, appears colorless. The spectrum, for example, appears throughout as a colorless band brightest in the region of the green. To such an eye a feebly-illuminated white surface, reflecting blue rays only, will appear grey, and will appear darker or lighter according to the amount of the blue light which is absorbed during its passage through the crystalline lens. A similar surface reflecting only red-yellow rays will likewise appear colorless, but its apparent brightness will not be affected by the greater or less coloration of the lens, for such rays are little, if at all, obstructed thereby. By means of a very simple apparatus Hess applies this principle to the problem in question.

The instrument is a long, horizontal, closed wooden box, emitting light through an aperture in the middle of one side. One-half of the aperture is covered by a blue glass, the other by a red-yellow glass, the line of junction being vertical. Standing behind each colored glass, and meeting it at the line of junction at an angle of 45°, is a

white reflecting surface, illuminated by an electric lamp in its own half of the box. The illumination of either can be increased or diminished by sliding the lamp along a scale, and can be lowered to any degree. Above the main aperture is a much smaller one serving as a fixation point for the eye under examination, so that the main aperture is pictured near to the macula, but not on it, and the influence of the macular pigment is avoided. The test made in a dark room, the eye being adapted to darkness, and the light proceeding from each half of the aperture so feeble as to appear colorless. If the position of the lamps be so adjusted that for one observer the two halves of the aperture appear equally bright, then an observer with more yellow color in his lens will see the blue half darker than the red, while one with less with see it lighter. In all tests the illumination of the red half remains constant, while that of the blue is varied until apparent equality is reached.

The margin of error, determined for several eyes separately, was found to be small. The average blue illumination giving apparent equality having been found, the extent to which it could be varied without apparent change was ascertained. For Hess himself an increase of 0.11 and a decrease of 0.18 were always recognizable; for some others the margin of error was still smaller.

By examining in this way a number of lensless eyes properly corrected—cases of cataract extraction with good vision—Hess obtained a standard by which to measure the absorption power for blue in normal lens-containing eyes. This *specific absorption* is expressed by the formula $\frac{n-1}{n}$ where n shows the number of times which the standard blue illumination must be increased for the eye in question in order to give apparent equality. Hess found that his own lens had a specific absorption of 0.248; in other words, that it absorbed nearly one-fourth of the blue light employed. This being ascertained, he could at any time, by adjusting the lamps for his own eye and then making the necessary reduction of the blue, re-obtain the standard for the lensless eye, and thus avoid errors which might have arisen through variations in the power of the electric lamps.

A series of healthy eyes belonging to different life periods were tested. The yellowness of the lens varied considerably, even in persons of the same age, but on the whole increased decidedly with the advance of life. Among eight persons over 50 years of age, seven showed an absorption of more than half of the blue light employed, in some cases much more; among twelve persons under 50 years of age, it

was less than one-half in every case. In this whole series the minimum absorption was 0.10, the maximum 0.85. For example, an artist (painter), aged 57, was tested with regard to the comparative color perception of his two eyes, one of which was normal, the other lensless through cataract extraction. His remaining lens absorbed more than 2/5ths of the blue light employed. In another case of the same kind, at the age of 74, the remaining lens absorbed more than one-half.

Hess was able to establish a scale of visible color, corresponding with the various degrees of color in the living lens as estimated by the test described, by using a graduated wedge of yellow glass. That part of the wedge which absorbs the same amount of blue as does the lens of a given eye has presumably the same color as the lens of the eye in question.

Further, he found it possible to demonstrate the color of the living lens by employing strong focal illumination with blue light obtained by placing a blue glass over an aperture in an opaque chimney surrounding a Nernst lamp. In the spectroscope this glass transmitted some green and some of the extreme red in addition to the blue. Under such illumination the pupil in early life appeared dark and nearly colorless; at 20 to 30 years of age it presented a shimmer of green; at later stages this became stronger and stronger. Between 50 and 60 the pupil of a perfectly normal eye was often surprisingly green, and sometimes decidedly brighter than the surrounding iris, especially was this so in brown-eyed people. When a lighter blue, which transmitted also some green and yellow-green rays, was used, the pupil in advanced life looked dark yellow. The phenomenon depends on the fact that the blue rays penetrate the lens a certain distance and are then reflected, thus passing twice through the layers which they penetrate.

These researches in "Xanthometry" of the lens prove beyond question that the color of the lens in advanced life does modify color perception to a considerable extent, and this fact may be confirmed without apparatus by any good observer whose one eye has been operated upon for cataract. The artist, aged 57, already mentioned, when shown a strip of white paper on a dark ground, declared it to be "white" to the lensless eye, "yellow" to the other; a blue paper appeared considerably brighter to the one than to the other. An architect, aged 51, saw a white paper "white" with the lensless eye, "cream-colored" with the other; a dark grey strip on a bright ground appeared "grey" to the operated eye, "sepia" to the other. A

patient, aged 74, said, 14 days after cataract extraction, that he saw with his operated eye "as through a blue glass."

The specific absorption in each case being known, a young person can form a judgment of the color perception of an elderly person by looking through a suitable yellow glass; on the other hand, an elderly person can recover the color perception proper to early life by looking through a suitable blue glass and increasing the illumination by the necessary amount. Hess suggests that an accurate estimate of their loss of blue perception, such as his test offers, should be of interest to artists. He notes the case of a celebrated artist who in advanced life painted by the electric arc light which combines great intensity with an excess of blue rays.

These interesting researches do not, of course, justify the supposition that a painter whose lens is yellow will necessarily use false proportions of blue and yellow in his pictures. If his lens absorbs, say, one-half of the blue light entering his eye from his model, it will absorb also one-half of that coming from his canvas, although the illumination of the two be different, provided that the two blues be of the same nature. Both model and canvas will appear less blue to him than to a younger man, but if the one correctly represent the other to him, it will do the same to the younger man. But there seem to be two possibilities of error. If, instead of accurately reproducing the feeble blue which he sees in his model, he strives to represent the stronger blue which he used to see, and would still like to see, he will be likely to overload his picture with blue; whereas, if his perception of blue is so far diminished that the fainter blues in his model pass unnoticed, his picture may conceivably be deficient in blue.

Coloration, Protective. For a complete account of this subject, which touches ophthalmology in an indirect fashion only, the reader is referred to the article on COLOURS OF ANIMALS by Edward Bagnall Poulton in volume vi, page 731, of the *Encyclopedia Britannica.* According to the opinion of Poulton, *cryptic coloring,* is by far the commonest use of color in the struggle for existence. *Protective resemblance,* for the purpose of defense, is far more common than *aggressive resemblance,* for the purpose of attack. The coloring is both *general* and *special,* to conform with the particular environment inhabited by the animal. The black and white stripes of the zebra, for example, blend together at a little distance in a proportion to match almost exactly the pale tint which arid ground possesses when seen by moonlight. In *special resemblance* the cryptic effect of coloration is aided by a combination of coloring, shape, and attitude, which produces a more or less exact resemblance to some one of the

surrounding objects such as a leaf or twig, a patch of lichen or a flake of bark, something which is of no interest to the enemy or prey. The animal is not hidden from view by becoming indistinguishable from its background, but it is mistaken for some well-known object. Some animals, as a further aid to concealment, have the power of adopting two or more appearances. Caterpillars and pupæ are *dimorphic*, green and brown. In some instances cryptic coloring changes in the same individual life, either with the change of season, or as the animal changes his environment in the course of his growth. Certain insects make use of the chlorophyl of their food to dissolve the color of the food which is transparent through their bodies. The most perfect cryptic powers are possessed by those animals whose colors can be changed into any tint appropriate to their environment. The chameleon is a well known example. It is also widely prevalent in fishes. These rapid color changes are due to changes in the shape or position of superficial pigment cells, controlled by the nervous system.

The use of color for warning or signalling *(sematic coloration)* is the exact opposite of this, its effect being to render the animal conspicuous to its enemies, so that it can be easily seen, well remembered, and avoided in the future.—(C. P. S.)

Color blends, Jennings'. A luminous ray of light when passed through a strong prism is decomposed, the component parts being differently refracted according to their wave length forming a continuous band—a spectrum, which to the normal eye appears to be composed of many colors. The longest light-waves are refracted least, corresponding to the red end of the spectrum; the short waves are refracted most, corresponding to the ultra-violet end of the spectrum. Between these limits the eye receives the impression of orange, yellow, green, and blue, and innumerable shades consequent on their blending.

Color-blind insects. After a long series of carefully devised observations, Plateau, the naturalist, came to the conclusion that insects are attracted to flowers by the odor rather than by the color and marking. He regards insects as virtually color-blind. The question has unusual interest from the biological standpoint, because it had been assumed by evolutionists that colored flowers had been developed through natural selection solely because the color serves to attract insects and thus to facilitate the transfer of pollen from one flower to another, upon which fertilization depends. If insects are really color-blind a new explanation of the colors and color-patterns of flowers must be sought; and no plausible explanation suggests itself, since the old teleological notion that things are made beautiful in nature to please

the eye of man has been totally discarded. In a recent paper before the St. Louis Academy of Science, Charles A. Turner tells of experiments proving to his satisfaction that bees can distinguish not only between colors, but also between color-patterns, and that this capacity is of value to them in recognizing plants that contain an abundant supply of honey.

Turner's view has the support of so high an authority as Professor Jacques Loeb, who long ago expressed the opinion that color may influence insects. But Loeb holds nevertheless that the dioptric apparatus of insects is very inferior to that of the human eye, whereas he has shown that the "chemical irritability" of insects—by which term he characterizes the sense of smell—is immeasurably superior to that of human beings, and possibly even finer than that of the best blood-hound. In proof of this, Loeb quotes the ingenious experiments of Bethe, which show that an ant, when taking a new direction from the nest, for the first time, always returns by the same path. "If the ant returning by this path bears no spoils, no other ants try this direction. But if it brings back honey or sugar, other ants are sure to try the path." The inference seems obvious that the ants are following a very delicate trail by the sense of smell. Loeb himself made an experiment which is still more convincing. "I placed a female butterfly in a cigar-box," said Loeb, "and closed the box. The box was then suspended half way between the ceiling and the floor of the room, and then the window was opened. At first no butterfly of this species was visible far or near. In less than half an hour a male butterfly of the same species appeared on the street. When it reached the height of the window its flight was retarded and it came gradually toward the window. It flew into the room and soon up to the cigar-box upon which it perched. During the afternoon two other males of the same species came to the box." This experiment seems to make it unequivocally clear that insects possess an olfactory sense of almost inconceivable delicacy.—(C. P. S.)

Color-blindness. Congenital disturbance of the color sense is of very wide spread occurrence. From the large number of examinations which have been made for the purpose of testing the color-sense it has been found that about three per cent. of males, and about two-tenths of one per cent. of females are thus affected. The so-called achromatics or monochromatics, see no different color at all, but only different shades. Such cases are very rare. More frequently we find people who can see only two colors in the whole spectrum; these are called dichromatics, and the study of their defect is of great practical importance to the employees of railroad and naviga-

tion companies. Except in rare instances both eyes are affected, and a distinct hereditary tendency has been noted in many examples. In other respects the functions of eyes which are color-blind are normal, and the cause of the condition has not been determined.—(C. P. S.) See **Color-sense and color-blindness.**

Color-blindness, Accidents due to. This subject is and will be treated under various captions in this *Encyclopedia,* especially under **Color-sense and color-blindness.**

Color-blindness, Achromatic. So-called color-blind people who see no different colors at all in the spectrum, but only different shades, are known as achromatics. See **Color-sense and color-blindness.**

Color-blindness, Acquired. Acquired color-blindness is frequently found in diseases of the optic nerve. The changes occur first in the peripheral parts of the retina, so that the areas in which the respective colors should be recognized in normal color-perception are more and more narrowed down until the fovea centralis begins also to be involved, at first still recognizing the colors of large objects, but later losing even this power and seeing everything grayish. Thus the following changes are observed in cases of typical atrophy. The perception of green is first disturbed, this appearing yellowish, later grayish, while all the other colors are well recognized: soon, however, the red is also seen grayish so that in orange only the yellow, and in purple only the blue is perceived. The green-blindness is therefore soon followed by red-blindness, and so it happens that red, green and yellow are confounded. Violet is considered to be dark blue. Later yellow also is lost and finally blue is no longer perceived as such.

In acquired color-blindness there is almost always a loss of the visual acuity or form-sense, while in the congenital variety this is usually normal. In acquired color-blindness the loss of color sense may be confined either to the central parts of the retina, as in central color-scotoma, or to peripheral parts of the visual field. Central scotomata for colors may occur alone, as in various affections of the optic nerve, choroid and retina, but the most frequent form is that which occurs in tobacco amblyopia. Here is observed an oval area, involving more or less the fovea centralis and extending as far as the optic nerve, in which colors are not recognized. Acute infectious diseases like typhoid and typhus fever, malaria, erysipelas, etc., may be followed by defects in color perception, usually inducing these by attacking the optic nerve.

A few cases are on record in which the color sense is disturbed while the visual acuity remains the same as before. Steffan carefully studied the case of a man 62 years old, who, after an apoplectic attack,

suddenly lost the power of distinguishing colors, which, as a color-printer, he had formerly been able to do very well. His vision remained perfect otherwise and the color-defect in both eyes was most pronounced for green. Four years later the status was the same, light sense and fundus oculi remaining perfectly normal. Steffan justly remarks that this case is probably the first by which a separate centre for color vision is established and he explains this sudden loss of color sense in both eyes by an apoplectic focus in the median line affecting the color centres in each occipital lobe. Very important also are those cases in which after concussion of the brain the color sense becomes affected either temporarily or permanently. Other more or less temporary anomalies of color-vision, as in hysterical amblyopia, or in hypnotism, seem also to depend on central disturbances.—(C. P. S.)

Color-blindness, Amnesic. As described by Wilbrand this condition has nothing in common with derangement of the color-sense as such. Whether it may occur without right hemianopsia has not been ascertained; all the cases thus far observed have been thus accompanied, indicating, as Wilbrand thinks, focal disease in the occipital lobe interrupting the paths between the centre for color-vision, which he believes to exist, and the speech-centre.

In amnesic color-blindness, although the patient can perform Holmgren's tests perfectly, yet he is unable to give to each color its name. He is either unable to give any name to the colors shown him, or he has only one term for all colors, or he describes colors by paraphrases or newly-formed words. He may also wrongly describe the color of familiar objects. On a superficial examination this symptom might be taken for true color-blindness, but it belongs, in fact, to the group of aphasia symptoms. The symptom of the same group with which it is most frequently associated is alexia.

If it be found in right-handed persons, and—where the lesion is a solitary one—only with lesion of the left hemisphere (producing right hemianopsia), the explanation of the circumstance may, Wilbrand thinks, depend on the association fibres of both color-vision centres passing close to the visual centre on the left side, on their way to the cortical speech centre: so that a lesion between their point of junction and the latter centre would be capable of producing amnesic color-blindness.

Color-blindness, Amnestic. Same as amnesic color-blindness.

Color-blindness, Békéss lantern test for. According to this observer (*Zeitschr. f. Eisenbahnhygiene*, vii. 1906) red-green blindness is the most important of the congenital disturbances of the color sense. Other forms are very rare and are generally due to affections of the

visual organ. They are blue-yellow, blue, and violet blindness, monochromatopsia and total color-blindness (achromatopsia).

Quantitative defects (dyschromatopsia) may be encountered in people with and without color-blindness. They require more intense light, larger objects and a longer time for the recognition of colors. Békéss found 5 cases in 655. All these forms are congenital.

The acquired color defects are generally caused by ocular diseases which by themselves exclude railway service. *For railway employes only persons with normal color perception should be accepted.*

A test applicable for railway purposes must have no or few sources of errors and must allow of easy and rapid application. Such tests, e. g., those of Holmgren and Stilling, are accused of not disclosing defective color sense sufficiently. Thus Nagel found, out of 300 railway employes previously examined with Holmgren's skeins, five color-blind; Collins, out of 1,778 soldiers of the railway brigade, previously examined with Holmgren's and Stilling's tests, 0.73 per cent. color-blind and 1.74 per cent. affected with color anomalies. Békéss, however, thinks that this is not a fault of the method but unskilfulness in its employment. Therefore railway surgeons must be taught to conduct these examinations correctly. One test, applied accurately, is better for the railway surgeon than the introduction of more. Békéss considers the methods of Holmgren, Stilling and Nagel as practically equivalent. Any new employe who passes these examinations is to be accepted. Those who make mistakes must be reëxamined by an ophthalmic surgeon.

In 1897, Békéss constructed a lantern with which the natural conditions existing on railways can be imitated. The same kind of lights and colored glasses as in the semaphores are used, the intensity of illumination is regulated by diaphragms, and, by interposition of glasses the optical relations of the atmosphere (fog, snow, etc.) can be simulated. The lantern proved very valuable, particularly in cases which are to be designated as weak in colors, and is highly recommended for the examination of railway employes.

Color-blindness, Chromatometric test for. Among the special tests for color-blindness, various forms of chromatometers are employed. The chromatophotometer of Chibret (q. v.) is one of the most valuable of these instruments. See, also, **Color-sense and color-blindness.**

Color-blindness, Congenital. Congenital color-blindness must not be confounded with the various disturbances of the color-sense which result from diseases of the optic nerve and retina, or with those which are seen in hysteria. See **Color-sense and color-blindness.**

Color-blindness, Congenital, Partial. Derangements of the perception of colors have been divided into two varieties: the one characterized by an absence of the power to perceive colors, or achromatopsia; and the other characterized by difficulty in distinguishing colors, or dyschromatopsia. The former condition, or color-blindness, is rarely *total*, as a congenital defect; generally it is *partial*. See **Color-sense and color-blindness.**

Color-blindness, Congenital, Relation of, to heredity and sex. Heredity and sex undoubtedly play an important part in the occurrence of color-blindness. *Total* color-blindness occurs almost entirely in the male sex, and frequently several brothers are affected with the same abnormality. Sometimes nystagmus and amblyopia are present, so that the eyes have often been regarded as abnormal in other respects.

It has been known for a long time that in *red-blindness* and *green-blindness* the anomaly usually passes from grandfather to grandson, while almost without exception the daughter of the color-blind father, and frequently even the son, remain free from the defect.

In the *American Journal of Medical Sciences* for April, 1845, Pliny Earle communicates the case of his own family, in which during four generations there were derived from seventeen marriages, thirty-two male descendants with eighteen color-blind, and twenty-nine female descendants with two color-blind. The fourth generation was divided into nine families of twenty-one male members with nine color-blind, and twenty-two female members with two color-blind. Once it occurred that neither father nor grandfather showed the anomaly, which, however, appeared in the great-grandson.

Horner of Zurich reported the case of an ancestor born in 1642 from whom seven generations descended with fourteen color-blind male descendants. The transmission of the anomaly was such that no female offspring ever suffered from it, that with one exception the color-blind fathers had sons with normal color vision, and finally that the color-blind male members had normally-seeing mothers, but were always (except the one son) the grandsons of color-blind grandparents on the maternal side. The transference of the defect to female members of a family is rare, but Cunier gives an observation which shows a heredity of the defect from the mother to the daughters in five generations, whilst the sons remained free; altogether twelve color-blind women, who could not distinguish cherry-red from blue. Five of these descended from one mother; the male members of the family, eight in number, were not color-blind. Interesting also is the fact that brothers show usually the same individual character of red-blindness or green-blindness.

The visual acuity with the color-blind of these types is usually very good, though of course errors of refraction occur. Nystagmus does not occur, and both eyes show usually the same kind of anomaly, if they are both color-blind; at least there is no case on record where the one eye was red-blind and the other green-blind.

Blue or yellow-blue blindness has thus far not been shown to be hereditary, but as this kind of anomaly is not found out so easily, and as only a few well-authenticated cases are known, the factor of heredity cannot be excluded. Holmgren found uniocular blue-blindness three times. This anomaly occurs also exclusively among men.—(C. P. S.)

Color-blindness, Congenital, Statistics of. From the examination of nearly seventy-two thousand men among widely scattered nations, made by trustworthy observers, it was found that two thousand six hundred and fifty-three, or 3.69 per cent., were color-blind. Out of fifteen thousand eight hundred and fifty-three females only fourteen, or 0.088 per cent., were color-blind. This points clearly to the prevalence of color-blindness among the males, and to its equal occurrence in different nationalities.

Color-blindness, Congenital, Tests for. See **Color-sense and color-blindness.**

Color-blindness, Congenital, Total. Color-blindness which is the result of pathological changes in the optic nerve, etc., is generally *total.* In congenital color-blindness, however, it is generally *partial.* Juler has reported the occurrence of total congenital color-blindness in three children, aged eight, five, and three, who were consecutive children in a family of seven. The unaffected four have healthy eyes, and are sound in body and mind. The parents seem healthy and of average intelligence. There is no history of consanguinity in the parents; both parents came from large families, and there is no clue that any relatives are similarly affected, nor is there any partial color-blindness in the family. In all three cases there was nystagmus and photophobia. Grunert in 1903 published a paper with abstracts of forty-seven previously recorded cases and a full account of five new ones. He explains the condition on the theory of absence or imperfection of the retinal cones. Nettleship published the earliest English cases and in 1909 reported that he had found records of thirty-two further cases besides those mentioned by Grunert.

No light is thrown on any hereditary taint, but the occurrence of several cases in one family appears to be fairly frequent.

The amblyopia is accounted for by the absence of cones, which are normally resident at and near the macula, causing a complete or relative central scotoma. The total color-blindness is also explained

by the absence of retinal cones. It is now well recognized that the cones possess the fine-form and color-senses. The color-blind rods permit only a small acuity of vision in a bright light from bleaching of the visual purple: in the dusk the accumulation of visual purple increases the capability of the rods, and thus the visual purple is the special apparatus for vision in the dark. But one case of total congenital color-blindness has been recorded in which there was normal visual acuity (Rachlmann), but here yellow appeared the darkest color and there was no photophobia.

Hessberg, in 1909 reported two families in which congenital total color-blindness affected several members. In one case the parents were cousins and had four children, three of whom,—two boys and one girl—were affected. In the other case the parents were not related, and three children—two girls and one boy—were affected. There was photophobia and rotary nystagmus in all these cases.—(C. P. S.) See **Color-sense and color-blindness.**

Color-blindness, Dichromatic. People who can see only two colors in the spectrum are called dichromatics. This is the most frequent form of color-blindness. See **Color-sense and color-blindness.**

Color-blindness, Futility of some tests of. For the past twenty years Edridge-Green in England, as well as Charles Williams, Nelson Black and others in this country, have pointed out the inadequacy of certain official tests for color-blindness, and their efforts have been seconded by many other ophthalmic surgeons. The results of these efforts is, in some cases, disappointing. Holmgren's wools are still scheduled as the official test both by the British Board of Trade and railway companies, and the examinations are frequently conducted by men who have no special knowledge of the physiology and pathology of color-vision.

Butler (*Brit. Med. Jour.*, Feb. 5, 1910) gives the histories of 5 cases of color-blindness who could easily pass the color tests with wools. carried out by the railroad company's inspector, but who were detected by the Edridge-Green color-perception lamp.

Color-blindness, Holmgren's test for. See **Color-sense and color-blindness.**

Color-blindness in extraocular diseases. From literature and his own observations, Hilbert (*Klin. Monatsbl. f. Augenheilk.*, p. 256, 1908) has noted many *disturbances of the color-sense in internal diseases:*

Fifteen cases of *erythropia*, of which 5 occurred in neurasthenia, 3 in hysteria, 2 in general paresis and 1 in each of the following affections,—epilepsy, choroiditis, atrophy of the optic nerve, anemia and hematemesis from interstitial hepatitis.

Twenty-two cases of *xanthopia*, viz.: 3 in neurasthenia, 1 in epilepsy, 2 in helminthiasis, 2 in icterus, 1 in insolation, 1 during menstruation, 3 in hemeralopia, 2 in influenza, 1 in diabetes, 1 in concussion of the brain, 1 in typhoid, 1 in otitis media, 1 in Weil's disease, 1 in arteriosclerosis. Here Hilbert remarks that the old Hindus were familiar with the yellow vision of icteric persons.

Twelve cases of *kyanopia:* neurasthenia 4, hysteria 1, atrophy of the nerve 1, nephritis 1, coryza 1, malaria 1, arteriosclerosis 1, influenza 1, apoplexy 1.

Sixteen cases of *chloropia:* neurasthenia 3, tabes 2, choroiditis 2, nephritis 2, prolapse of iris 1, hemicrania 1, syphilis 1, paresis 1, epilepsy 1, sympathetic ophthalmia 1, psychosis 1.

Four cases of *ianthinopia:* otitis media 1, choroiditis 1, tabes 1, influenza 1.

The enumerated disturbances occurred in different forms. Either the whole visual field appeared in one color, or the sensation was perceived in colored scotomas or was of hemianopic character. In the majority of cases, in 44 out of 71, the phenomenon was due to diseases of the nervous centres, and Hilbert concludes that also in affections of other organs it had a central cause and is to be considered as a kind of hallucination of color.

Color-blindness, Incomplete. In using Holmgren's method for the detection of color-blindness (q. v.) a person may be found to be color-blind when the green test-skein is presented. We next take the rose-purple test-skein. If he confuses the colors, he will select either the light or deep shades of blue and violet, especially the deep, or the light and deep shades of one kind of green, or gray inclining to blue. A candidate who is proven color-blind by the green test-skein, and who in the rose-purple test selects only purple skeins, is incompletely color-blind. See **Color-sense and color-blindness.**

Color-blindness, Inconveniences and dangers of. The color-blind occasionally make curious blunders, which although they may not be dangerous to life, yet may cause serious confusion and annoyance, as for instance the case of a government clerk mentioned by Carter, "whose duty it was to check certain entries in relation to their subject-matter, with ink of one or of another color, and whose accuracy was dependent upon the order in which his ink bottles were ranged in front of him. This order having been accidentally disturbed, great confusion was caused by his mistakes, and it was a long time before these mistakes were satisfactorily accounted for. An official of the Prussian post-office again, who was accustomed to sell stamps of different values and colors, was frequently wrong in his cash, his

errors being as often against him as in his favor, so as to exclude any suspicion of dishonesty. His seeming carelessness was at last explained by the discovery of his color-blindness, and he was relieved of a duty which it was impossible for him to discharge without falling into error.''

Stratton (*Pop. Science Monthly,* March, 1908) points out the *danger of ''white'' light signals being mistaken for window-lamps,* etc. When green comes dimly to the eye, particularly if coming through smoke, and when sight has grown accustomed to the dark, it does not appear green at all, but as a pale and ambiguous light that is indistinguishable from white. More than one instance has occurred where the failure to observe a ''distant'' or ''caution'' signal, which is often green, has been a large part of the cause of fatal accidents. But the core of the present system is red. A ruby glass placed before a semaphore lamp, by cutting off the green, blue and violet rays, leaves the light often about one-fifth as intense as when the red glass is removed. Thus, in a cluster of remote signal lights, the white lights usually far outshine the red, the sign of danger. If in the laboratory a ''white'' semaphore light was reduced in brightness to where in the darkness it could just be perceived, and a railway ruby glass placed before it, the very least increase in brightness at which it could be observed was fourteenfold. Under ordinary conditions an increase of thirtyfold has been necessary before any conscious impression of the light was made through the red glass. A man who had passed the color tests required it to be increased seventy times in order to perceive it. The intensity of light which in some other colors is sufficient to make an impression, does not in red penetrate the mind, yet, all things considered, it may be the best color sign for danger. The spatial character of objects such as shape, position, and especially movement, are more naturally and quickly noted than the color. Although there may be some disadvantages, Stratton believes that an effective and safe system of signals might consist of a row of lights—e. g., imagine incandescent lights inserted in the signal arm used by day, lengthened and otherwise modified. Though a considerable distance be between lights, yet they appear as a continuous line. Experiments show that the main directions of such a line can be caught by the normal eye when the length is about a thousandth of the distance from which it is to be read. Such a system is used in the navy. Two movable arms, each provided with a row of incandescent lights, here rapidly convey, by the direction in which they point, their message from ship to ship, or to the shore. Numerous instances of those defective in color-sense having successfully passed the color tests are recorded.

As most color-blind men are either red-blind or green-blind, and as white, red, and green, are the colors of signals, the following table shows at a glance the most frequent mistakes with regard to these signals:

From this table it is clear how dangerous to the travelling public a red-blind or a green-blind man would be, as he might mistake a red signal for a green one, or a green signal for a white one, or vice versa.

Color of Signal.	To a Red-Blind Person appears	To a Green-Blind Person appears
Red.	Green or yellow [1]	Red or yellow
Green the dominant color of signal being equal to green of spectrum well to the red side of the neutral band	Grayish green or grayish yellow	Grayish red or grayish yellow.
Green: the dominant color of signal being equal to green of spectrum at the neutral band of the green-blind.	Whitish green or whitish yellow [2]	Whitish
Green: the dominant color of signal being equal to green of spectrum at the neutral band of the red-blind	Whitish	Whitish blue.[3]
Green: the dominant color of signal being equal to green of spectrum well to the blue side of the neutral band.	Whitish blue.	Grayish blue.
White.	White.	White.

Table Showing the Mistakes which a Color-Blind Person Makes with Regard to Signals.

It is true that in a testing-room a color-blind might recognize the colors by their relative brightness and dilution with white, for which these color-blind have indeed a very fine power of distinction. For, as the table shows, the red and different green signals look different, for example, to a red-blind man, and this power of distinction by their relative luminosity has been confirmed. Men have been found who could not pass Holmgren's test, nevertheless they differentiated more or less correctly the colors of the lanterns in the office if the light was not diminished at the same time by some means or other. It might be supposed that if the colors of the signals could be rightly given in the testing-room they would be equally well recognized elsewhere. But it must not be forgotten that the atmospheric conditions of the testing-room are often very different from those existing outside. For the color-blind depends in his judgment mostly on the brightness of the colors, which factor is frequently changed by a misty atmosphere, or

by dirt on the cloth or the glass, and under such conditions he may easily confound the white signal of safety with the green one of caution, or even with the red one of danger. Any judgment of the color of a signal which depends upon its brightness would be fallacious.

It may be said here that many evil results have followed the attempt of color-blind officials to do work that should be carried on only by the normally sighted. Among them are the following:

On the night of Nov. 15th, 1875, near Lagerlunde, in Sweden, two express trains ran into each other, and one passenger and eight employees of the road were killed, and many others injured. It developed at the inquest that this accident was caused by color-blindness. About one year later, through the efforts of Holmgren a rule was adopted whereby only persons with normal color-vision are employed in the railroad service of Sweden.

In the *Annual Report of the Supervising Inspector General of Steamboats,* to the Secretary of the Treasury, Washington, 1880, this record is as follows: "On the night of the 5th of July, 1875, there was a collision near Norfolk, Va., between the steam-tug Lumberman and the steamship Isaac Bell, the former vessel bound to, and the latter from, Norfolk. The accident occurred about nine P. M. on an ordinary clear night, under circumstances which until recently seemed more or less mysterious. The master of the steamer and all his officers made oath that at the time signals were made to the tug, the latter was from one to two points off the steamer's starboard bow, and consequently the steamer's green light only was visible to the approaching tug. Yet the master of the tug, whose statement was unsupported by any other testimony, asserted that the steamer's red light was exhibited, and signalled accordingly. The discrepancy in the statement was so great that many persons uncharitably charged the master of the tug with being drunk, although no evidence was offered in support of the charge. By this accident ten persons lost their lives. Upon a visual examination of this officer, under the rules, during the past summer, and during which time there had been no question as to sight, by the Sergeant of the Marine Hospital at Norfolk, he was found to be color-blind, two examinations having been accorded him, with an interval of ten days between them."

George Wilson in 1853-55 in different papers read before the Royal Scottish Society of Arts was the first to propose color-vision tests for employees of railroad and marine service, but his efforts in this direction received much less attention than they deserved because it

was at just this period that the ophthalmoscope was discovered, and was occupying the attention of ophthalmologists.

Every color-blind person who is employed on a ship or railway, must in certain positions be a source of danger to the public. As an example in 1892 there were employed by the different railroad companies of the U. S. 821,415 men, while the miles covered amounted to over 171,563. Taking 3.69 as the percentage of color-blindness among men, we shall get 30,310 color-blind men. These figures appear to show a greater risk of accident than we find realized in actual working, and it is manifest that there are compensations to be taken into account. In the first place the term "color-blind" is itself in some degree misleading, for it must be remembered that the signals to which the color-blind person is said to be "blind," are not invisible to him. To the red-blind, the red light is a less luminous green, to the green-blind, the green light is a less luminous red. The danger arises because the apparent differences are not sufficiently characteristic to lead to certain and prompt identification in all states of illumination and atmosphere. It must be admitted therefore that a color-blind driver may be at work for a long time without mistakes; and it is probable, knowing, as he must, that the differences between different signal-lights appear to him to be only trivial, that he will exercise extreme caution. Then it must be remembered that lights never appear to an engine driver in unexpected places. Before being intrusted with a train he is taken over the line and is shown the precise position of every light. It must be also remembered that to overrun a danger signal does not of necessity imply a collision. A driver may overrun the signal and after doing so he may see the train or other obstruction on the line and may stop in time to avoid an accident. Although accidents may be avoided by a combination of circumstances such as have just been mentioned, the fact remains that collisions attended with loss of life and damage to property are of frequent occurrence, and there is reason to suppose that color-blindness is the predominant, the unsuspected, factor in many cases. See **Color-sense and color-blindness**; as well as **Employes, soldiers and sailors, Examination of the eyes of.**—(C. P. S.)

Color-blindness in insects. See **Color-blind insects.**

Color-blindness in pilots and light-house keepers. Claiborne (*U. S. Naval Proceedings*, 34, 1909) reminds us that to the green-blind man, green seems like dirty grey, and that to the red-blind man red is green. A pilot totally color-blind for red will, of course, see green when he looks at the port light, and may think it is the starboard. A green-blind man will see dirty white when he looks at the green or starboard

light. But, again, let it be remembered that completely red-and green-blind people sometimes escape detection, and that those partially blind for red—and particularly those for green—frequently do so.

The partially red-blind man is not so great a source of danger, because his vision at least gives him the idea of a modified green, but the partially green-blind man may readily mistake certain shades—particularly light ones—of green for white, and the fact that the misty atmosphere often causes confusion when green is looked at by those with normal color perception has already been sufficiently emphasized. It is this man, the *partially green-blind one, who is the fruitful source of danger in seafaring.*

The present system, then, has the following disadvantages: The possibility of total color-blindness for red or green. The possibility of partial color-blindness for red or green. The confusion which exists in the minds of most men as to the distance of red and green lights. The added confusion which is caused by comparing red and green and white. The reliance for the estimation of distance upon the intensity or brightness of a light. The utter impossibility of judging the distance of a single light by the increase of its size in approach or regression respectively.

The advantages of the system suggested by the writer are: The elimination of color-blindness, partial or complete; the absence of the mental confusion which results from the simultaneous comparison of red, green, and white, or any two of them; the substitution of red and green by a uniform standard—white—recognizable by all who have the requisite amount of vision for seafaring; the employment of definite geometrical figures to indicate the starboard and port—a star for the starboard and two lights in a vertical series for the port; the reliance for estimation of distance upon a known visual angle, determinable by the range-finder with mathematical accuracy; the possibility of the estimation of the angle at which a ship being approached on the starboard by the changing angles at which the horizontal vertices of the parallelogram are seen; the substitution of the white parallelogram for coast light houses in place of those at present in use. See **Employees, soldiers and sailors, Examination of the eyes of.**

Color-blindness, Lantern test for. To control and also to substitute the various wool-tests, lanterns are employed for detecting color-blindness. Many different models have been devised for this purpose, among which the ones designed by William Thompson, Charles H. Williams, and Edridge-Green are perhaps the most practicable. Concerning lantern tests, Thompson says, "Whilst the wool-tests have been accepted universally as requisite for the detection of color-

defects, the employees of railroads and their friends have always objected to their use as having no relation to their daily duties, and have demanded such colors as are employed as signals. Furthermore, for two-fifths of the time during the night of an employee's life, he is expected to govern his actions by colored lights, and hence a lantern, which can imitate the night signals in form, color, intensity, and size, as they appear under all obstructions caused by rain, snow, fog, and smoke, is desirable. Its power over the wools to detect the central amblyopias of tobacco, alcohol, drugs, and disease, that would not be revealed by the skeins, makes it a necessity. See **Color-sense and color-blindness.**

Color-blindness, Lantern test for, Donders'. This test for color-blindness consists of a series of colored glass squares so arranged that they may be brought separately in front of an opening illuminated by a lamp. It is especially intended to be used in testing railway and steamship employees.

Color-blindness, Monochromatic. People who see no different colors in the spectrum, but only different shades, are called monochromatics. See **Color-blindness, Achromatic.**

Color-blindness, Partial. All typical cases of partial color-blindness are characterized by the spectrum appearing to them dichromatic and by the presence in it of a *neutral band*,—i. e., of a spectral region that looks to them either white or gray. According to Helmholtz's theory, which is followed by Holmgren, three classes are distinguished, blue-blindness, green-blindness, and red-blindness. See **Color-sense and color-blindness.**

Color-blindness, Pseudo-isochromatic plates for testing. See **Color-table, Pseudo-isochromatic, of Stilling.**

Color-blindness, Re-examination for. There can be no doubt that color-blindness of the congenital type is never acquired; therefore it can be only the acquired form that can appear in an individual who has once successfully passed a carefully conducted examination for color-blindness. As abuse of tobacco and alcohol, concussion of the brain, cerebral disease, diabetes mellitus albuminuria, syphilis, rheumatism, and even some acute fevers may produce color-blindness, it seems necessary that the employees should be retested from time to time, say every third year. It would probably mostly suffice to test the form sense alone, though in doubtful cases, especially of young men, an ophthalmic examination of the central and peripheral color-vision ought not to be omitted.

The tests used for the detection of color-blindness, as well as the colors of the signals used, should be re-examined from time to time by

a scientific expert, not only to protect the public properly, but also to insure justice to the men.—(C. P. S.)

Color-blindness, Seat of. The complete nervous apparatus for the perception of color consists essentially of three parts,—the *retina* with the chromo-sensitive end organs, the *conducting fibres,* and the *cerebral centres.* The cause of color-blindness may therefore lie in either of these three organs. With regard to *congenital* color-blindness, the fault is undoubtedly in the photo-chemical substance of the retina, or at any rate in front of the chiasm, as there are undoubted cases of uniocular color-blindness. *Reduced color-sense* must probably be also attributed to abnormal conditions of the photo-chemical substances, while *color-ignorance* of course has its cause in uneducated or undeveloped centres. With reference to *acquired* color-blindness, we find that any or all of three factors may be at fault. A lesion of the retina, a defect of conducting power in the optic fibres, or a pathological change in the cerebral centres for color-vision may explain a special case.

According to Leber, in diseases of the retina color-blindness sets in only when the pathological process has gone on to secondary atrophy of the inner retinal layer (the layer of nerve-fibre) and of the papilla nervi optici. Stilling found the color-sense intact in chorio-retinitis, glaucoma, retinitis albuminurica and apoplectica, and hemorrhage into the macula lutea in chorioiditis. This fact, that retinal, or chorio-retinal diseases produce reduced vision without color-blindness, whilst diseases of the optic nerve produce reduced sight with more or less color-blindness, seems to indicate that the photo-chemical substances have a greater power of resistance to pathological influences than the axis-cylinders, and that the former become much affected only when the latter begin to be diseased. It seems then, that acquired color-blindness is more apt to be due to lesion of the optic nerve or of the cerebral centres. If due to lesion of the conducting fibres, it is plain that form-vision must be disturbed also, as is the case in atrophy of the optic nerve, etc. But if the lesion (concussion, blood-clots, tumor, etc.) is in the cerebral centres, especially of the occipital lobes, then with the color-sense the form-sense may or may not be affected, according as the morbid process extends to one or both centres.—(C. P. S.)

Color-blindness, Special tests for. These include the use of the spectroscope, and various forms of chromatometers, the chromotophotometer of Chibret being the instrument that is perhaps the most valuable. See **Color-sense and color-blindness.**

Color-blindness, Spectroscopic test for. The spectroscope, and various

forms of chromatometers are used in special tests for the detection of color-blindness. See **Color-sense and color-blindness.**

Color-blindness, Stilling's pseudo-isochromatic plates for testing. These consist of a series of plates (ten in number), each plate containing four squares filled by small, irregular, colored spots, among which other spots in a confusion color, made to conform to an arabic figure, are placed. The test-plate is held in a good light, and the examiner requires the subject to distinguish the tracings. See **Color-sense and color-blindness.**

Color-blindness, Temporary artificial. Burch used a beam of sunlight from a heliostat, decomposed it by prisms and concentrated each color on his eye by a lens of 3 in. focus. He found that by continued exposure of the eye to light of one color all direct sensation of the color used was for a time abolished. His most important observation was that fatigue of the retina by yellow light produced partial blindness for red and green, a fact which gave strong support to the Young-Helmholtz theory of color-vision.

Edridge-Green and Devereux Marshall criticised Burch's method of producing fatigue as too violent and dangerous. They exposed themselves to the pure yellow light of a sodium flame for periods of 3 to 15 minutes and the results of their investigations differed in many respects from those of Burch and tended to show that the psycho-physical theory of color-vision of Edridge-Green was upheld, while neither the Young-Helmholtz theory nor that of Hering would account for the phenomena.

Color-blindness, Thomson's test for. See **Color-sense and color-blindness.**

Color-blindness, Total. Total *achromatopsia* may be either congenital or acquired. In people who are totally color-blind, the spectrum appears perfectly achromatic. Yellow, or mostly the green, appears as the brightest gray, from which, towards both ends the spectrum becomes gradually darker till it finally becomes almost black.

Little difference exists between the authors of different schools in the description of the manner in which the colored world appears to individuals of this class. The whole spectrum appears to them in different shades of gray, with the maximum of brightness in the yellow or the green. A case has been reported of a totally color-blind teacher, who compared the spectrum to a delicately executed lead-pencil drawing, which from the sodium line became gradually darker towards both unshortened ends. Any photographic print of flowers or colored objects will indicate the appearance, but with this difference, that here the blue parts appear the brightest. This, according

to Hering, would mean that all the chromatic substances had disappeared, only the white-black one remaining. With regard to the Young-Helmholtz theory, Foster thinks that such cases, well authenticated, would be almost fatal to it; but it is even easier to comprehend these cases by this theory on the assumption that all the three photochemical substances have become alike, as is amply justified by the color-vision of the extreme periphery of our retina. Further, such cases that have been reported in which the principal sensation was green, and another in which it was blue-violet, can thus be easily explained by assuming that all color-sensitive terminals are provided with a substance very similar to the green—or the blue—sensitive material of the normal eye.

Hans Gertz (*Arch. f. Augenhk.*, 70, p. 228) reports the case of a girl, aged 16, whose parents and sisters had normal color sense, who suffered from childhood of photophobia. She had horizontal nystagmus, vision with + 4.00 5.30, visual field normal. The fundus had the typical aspect of blond persons. At her 12th year it was noticed that she could not discern colors. Asked to match from Holmgren's skeins green she selected whitish, saturated carmin, whitish czar-blue, greenish-blue, light-grey and one with a tint of violet. Purple was matched with saturated carmin, whitish-red, yellowish-green, greyish-green, bluish-green, dark czar-blue, grey. In determining the ends and the lightest place of a prismatic spectrum, 15 cm. long, of the filament of an incandescent lamp on a white screen, her statement corresponded with the perception of Gertz for the short-waved rays. She placed the border of the long-waved side into orange and did not see the whole field of red, which for Gertz was rather light. The lighted point of the spectrum lay for her between yellowish-green and greenish-blue, for Gertz in yellow. This test was made immediately after entering the dark room from daylight. The adaptation for dark was for Gertz and patient parallel. The decrease of the central sensitiveness of light for subdued illumination was a little greater than the normal, and the central sensitiveness for daylight somewhat less than the paracentral.

Cantonnet (*Archives d'Ophtalm.*, May, 1913, p. 289) has added a case to a list of thirty-nine cases which Grunert had collected from literature in addition to his own five. The subject when first seen was fourteen years old, and when seen again was twenty. In the interval of six years the findings had suffered no change whatsoever. The patient had no hereditary stigmata, and was intellectually and physically normal. His parents were not blood relatives. His eyes presented no external anomaly except a slight horizontal nystagmus

with a rotary tendency. In moderate light there was no photophobia, but in strong light yellow glasses were worn, and strong sunlight was distressing. His corrected vision was 1/3, when the test types were moderately illuminated; with strong illumination the vision was markedly less. The field of vision was normal for form. Color sense totally absent. The different colors are distinguished according to their luminosity; all colors of the same shade are grouped together. No hemeralopia present. The media are all clear, and the fundus, with the exception of a slight anomaly of the vessels and an intense pigmentation, normal.

Cantonnet holds to Parinaud's theory of "an anomaly of the cone retina," the rod retina being normal. As a microscopic examination of this anomaly has not yet been possible, one is forced to theorize. The clinical import is that were we to bear this anomaly in mind and to look for it in those who present congenital anomalies of vision, we would be more likely to find it oftener, i. e., we should oftener detect subjects who are "color-blind without knowing it."—(C. P. S.)

Color-blindness, Uniocular. There are well-authenticated cases of uniocular color-blindness which can be explained only by an ante-commissural defect, which, from the fact that the visual acuity is not reduced, must most probably be placed in the retina. See **Color-sense and color-blindness.**

Color-blind pedigrees. Nettleship (*Trans., Oph. Soc., U. K.*, June, 1912) explained the pedigree of four families containing color-blind members with certain unusual facts connected with them. They all contained one or more color-blind females. According to the Mendelian scheme of inheritance where color-blindness is found in a female it is to be expected that her father will have been color-blind and that if she has sons all of them will be color-blind. A congenital deformity, crooking of the little finger, occurred in two of the color-blinds and one of the normals in direct descent. A similar condition had been noticed in some other members previously found in another pedigree of color-blindness which he had published. Two of the pedigrees showed a pair of female twins in each of which one was color-blind and the other was not. He mentioned that the only other recorded case was one by Reber of male twins. In one of his own cases the twins were probably "similar," for they had a common placenta and both children were almost exactly alike. The tests he used for the detection of the color-defect were wools, Nagel's test and the spectroscope. In the other pair of twins the resemblance to each other was not so marked and it is very doubtful if these were "identical" twins. Nettleship also gives an account of a pedigree of color-blindness in a family worked out by C. H. Usher (Aberdeen). The

pedigree showed the union of two unrelated stocks both containing cases of color-blindness. A color-blind male married a normal female who presumably carried the condition. Her family consisted of three sons, two of whom were color-blind, and five daughters who were all healthy and who showed no defect in this respect. See **Color-blindness, Congenital, Relation of, to heredity and sex.**

Color, Broken. A term used by artists to designate any color produced by a combination of two or more pigments.

Color-centre. It is as yet uncertain whether color-perception is produced by the same cells that cause light-perception, and whether the centre for color lies in another layer than that intended for the perception of light, because up to the present time no anatomical observations have been recorded. The visual centre is situated in the cortex of the calcarine fissure. The cortical color-centre does not at any rate lie in the ventral cortex, as was formerly assumed. The centre for perception of position in space, in the same sense as the centres for light—and color—perception, probably does not exist, for the sense of position in space is caused by several references to the action of the muscles of the eye, etc., whose central point Knies places in the cortex of the occipital lobe.

Cases are known in which, as in apoplexy, the color-perception of the homonymous halves of the fields of vision is lost, whilst the peripheral extent of the field for white and the central and peripheral acuteness of vision of homonymous color-blind halves of the visual fields are not altered, or only to an unimportant degree. Cases have been reported in which the acuteness of vision and the visual field for white remained normal for years after an apoplectiform hemianopic color-blindness (so-called color-hemianopsia) had appeared as bilateral color-blindness in eyes which had formerly good color-perception.

This peculiarity of the sudden and permanent loss of power of color-perception in both eyes, or in the homonymous halves of the two fields, whilst the eccentric acuteness of vision and the extent of the fields of vision for white are normal, can be explained only by the sudden separation of that portion of the cortical surface which affects the power of the perception of color, without any destructive interference with the ganglion-cells in which the perception of light originates.

These relationships have been studied carefully by Wilbrand, who asserts that the so-called centre for color-perception must be situated in the outer cortical layers of the visual centre, and over that cell-region which appeared as the centre for "clear-sight perception." Oppenheim reported a case in which following a fracture of the left side of the occiput, there was the single cerebral symptom of

right homonymous color-hemianopsia. The skull was trephined and the affected portions of bone chiselled off. A marked depression was found, with several splinters and hairs situated in the deepest part. The bone was removed; the dura was not opened. The result was successful as to the patient's general condition, but the color-hemianopsia remained unchanged.—(C. P. S.) See **Color-blindness, Seat of.**

Color chart, Donders'. This test for color-blindness consists of a card containing eighteen squares of different colors.

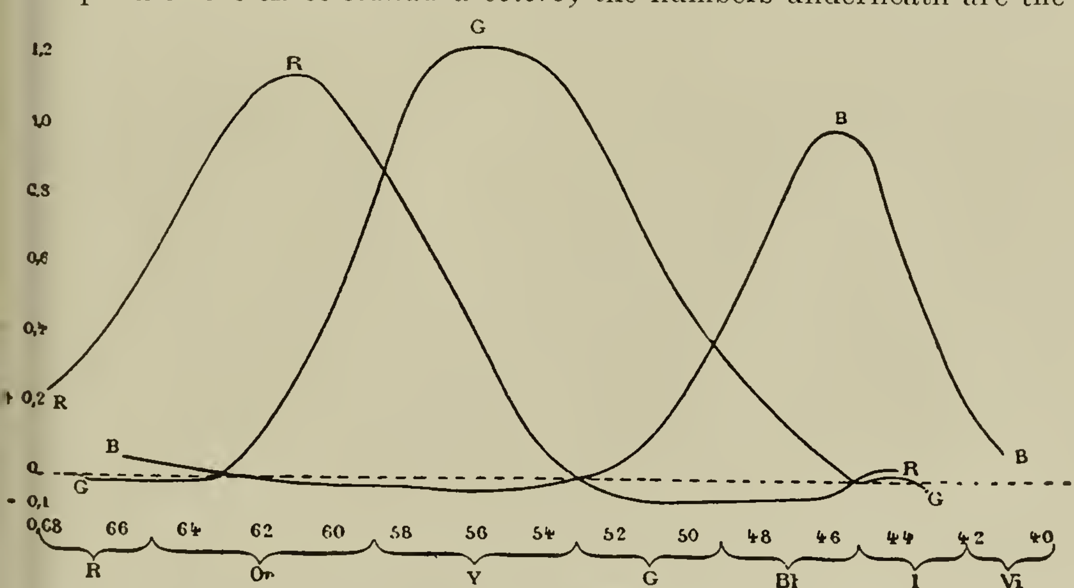
Color-chord. A term used by artists to designate a harmonious group of colors; a satisfactory color-scheme.

Color, Complementary. Two simple colors, taken from different parts of the spectrum and mixed in a certain ratio, will give white. Two such colors are called complementary. See, also, **Color-sense and color-blindness.**

Color, Compound. A color made up of a mixture of two or more primary colors.

Color-contrast. A modification of the visual impression that takes place when two or more objects of different color are viewed simultaneously or in quick succession, attributed to the fact that the action of the portion of the visual apparatus that takes cognizance of a particular color calls into action also an adjacent portion, producing the impression of another color, or produces in itself a state of fatigue that leads to the impression of the complementary color. See **Color phenomena of contrast.**

Color curves of Maxwell. The three curves, designated R, G, B, correspond to the three *standard colors;* the numbers underneath are the



Color-Curves of Maxwell.

wave lengths of the different colors of the spectrum, and the position of the three points in which the curves cut the vertical line corresponding to each of the colors, indicates the quantities of the three *standard colors* needed to produce the mixture.

Color cylinders, Badal's. One of the many devices for the detection of color-blindness.

Color defects. See **Color-sense and color-blindness.**

Colored after-images. These may be either of the same color as the object or of a complementary color. See **Color-sense and color-blindness.**

Colored crayons, Adler's. One of the numerous tests for color-blindness; not used very extensively, as it is said to be unreliable.

Colored glasses. Tinted lenses. Colored protective lenses. These are used in the after-treatment of ophthalmic operations to protect the eyes from light, especially during convalescence after operation on the globe. A variety of colors is to be had, notably green, blue, amber, and amethyst. If well-fitted as to pupillary distance and relation to the lashes, they offer considerable protection.

Sir Wm. Crookes (*Proc. Royal Soc.,* Nov. 13, 1912) has been experimenting on the effect of adding various metallic oxides to the constituents of glass in order to cut off the invisible rays at the infra-red end of the spectrum, and thus to prepare a glass which will cut off those rays from highly heated molten glass which damage the eyes of workmen, without obscuring too much light or materially affecting the colors of objects seen through the glass when fashioned into spectacles.

Single metals were at first tried in varying quantities to see if from the color and properties communicated to the glass they were worth further examination. Each specimen is cut and polished into a plate 2 mm. thick. The plate so prepared is first put into the radiometer balance to find the percentage of heat cut off. It is then tested in the spectrum apparatus to ascertain the upper limit of transmission of the ultra-violet rays; next it is tested in Chapman Jones's opacity meter to estimate the percentage of luminous rays transmitted, and finally the color is registered in a Lovibond's tintometer.

The following elements were selected as likely to be worthy of further experimentation by combining the metals, two, three, or four at a time in one glass so as to enable the advantages of one to make up for the shortcomings of another: Cerium, chromium, cobalt, copper, iron, lead, manganese, neodymium, nickel, praseodymium, and uranium.

While bearing in mind that the chief object of this research is to find a glass that will cut off as much as possible of the heat radiation,

he has also attacked the problem from the ultra-violet and the transparency points of view. Taking each of these desiderata by itself, he has succeeded in preparing glasses which cut off more than 90 per cent. of heat radiation, which are opaque to the invisible ultra-violet rays, and are sufficiently free from color to be capable of use as spectacles. But he has not been able to combine in one specimen of glass these three desiderata in the highest degree. The ideal glass which will transmit all the colors of the spectrum, cutting off the invisible rays at each end, is still to be discovered.

So far as transparency, however, is concerned, it will not be an unmixed advantage for the sought-for glass to be quite clear and colorless. The glare of a strong light on white cliffs, expanses of snow, electric light, etc., is known to be injurious to the eye, and therefore a tinted glass combining good obstruction to the heat radiation and ultra-violet rays is the best to aim for.

For ordinary use, when no special protection against heat radiation is needed, the choice will depend on whether the ultra-violet or the luminous rays are most to be suppressed, or whether the two together are to be toned down. Ordinarily the visible spectrum is assumed to end at the Fraunhofer line K, λ 3933, but light can easily be distinguished some distance beyond by the naked eye. It may therefore be considered that the ultra-violet rays which are to be cut off on account of their possible injurious action are those of shorter wave-lengths than, say, λ 3700. Many glasses have been prepared for this purpose, all of which are opaque to rays shorter than λ 3700. The colors are pale-green, yellow, and neutral; they transmit ample light so that a choice of tints is available to suit individual taste.

In a series of experiments made a number of years ago, Fieuzal demonstrated that a certain tint of amber, containing more of the green than the amber commonly used (which is more yellowish), had the greatest effect in excluding the maximum amount of actinic light while at the same time excluding the minimum amount of illumination.

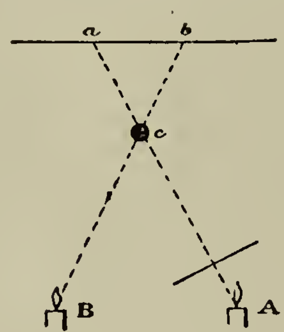
Hunters, snow-climbers, explorers in the Arctic regions, etc., have found empirically that glasses of a certain color give them great relief. The various tints of amber, the so-called euphos and Fieuzal lenses are all used for this purpose, and are to be preferred to either smoked or blue glasses.—(C. P. S.)

Colored glass test for malingering. There are numerous tests with colored glasses, to detect pretended amblyopia. The method generally employed, or some modification of it, is known as Snellen's method. The patient is required to look at alternate red and green

letters. The admittedly sound eye is now covered with a red glass, and if the green letters are read, evidence of fraud is present. Instead of a red glass, a green glass may be used, through which the red letters will be invisible. Ingenious letters, based upon the fact that red upon a white background viewed through a red glass disappears, and viewed through a green glass appears black, have been devised. See **Blindness, Simulation of.**

Colored protective lenses. See **Colored glasses.**

Colored shadows. If a white and a colored light are made to fall on a white surface or a surface of neutral tint, and an opaque object, as a pencil, be held so as to cast a shadow of equal density from each light, the shadow from the white light will appear to be the color of the colored light, while the shadow from the colored light will appear



Experiment with Colored Shadows (Tscherning).

in its complementary color. For example, if the colored light is red, the shadow from it will appear to be green.

Let A and B be two candles, of which A may be the brighter; in front of A we place a red glass; a and b are the shadows which the stick c forms on the white screen. The screen illuminated by the white light from B and the red light from A, should appear whitish-red, but the red is scarcely perceptible; b, which is illuminated only by the red light from A, appears red, and a, which should appear white, appears green, by contrast. We can also make the experiment with daylight and that of a candle, in which case there is no need of the colored glass, since the colors of the two lights already differ. We begin by illuminating the screen with daylight; we see the screen white and the shadow black (gray). On lighting the candle the screen still appears white, although it would seem that it ought to appear yellow, since it is partly illuminated by the yellow light of the candle; the shadow, which just now appeared gray, has become yellow by the illumination of the candle, and the other shadow, which receives the daylight, appears blue "by contrast." —(C. P. S.) See, also, **Color-sense and color-blindness.**

Colored vision. As stated in Wood's *System of Ophthalmic Therapeutics* (page 802), almost every form of this symptom, from *erythropsia* or red vision, sometimes seen in neurotic subjects and occasionally brought on by the excessive use of coffee, *cyanopsia* or blue vision, seen after cataract extraction, yellow vision, *xanthopsia*—a symptom of santonine poisoning—and *green vision* (described by Dodd) are on record. Apart from the removal of the cause, when that is possible, the treatment is entirely empirical. Preparations of gelatine, pulsatilla, the bromides, etc., have been used with more or less success.

Among the anomalies and diseases of the optic nerve that cannot be cured, improved or, at least, can be only imperfectly reached by non-surgical treatment are the following: congenital atrophy, tumors of the optic nerve, hyaline bodies in the nerve head, optic aplasia, coloboma of the optic nerve, congenital cupping and pigmentation, optic neuritis with nasal discharge, hemorrhage into the sheath of the optic nerve, color blindness or congenital amblyopia for colors, argamblyopia or amblyopia from non-use and traumatisms of the nerve. See, also, **Chromatopsia.**

Color-field in glaucoma. The contraction of the color-fields in glaucoma is usually proportionate to that of the form-fields, but this rule meets with exceptions. Under the influence of operative measures or miotics very decided improvement in the extent of the visual field may take place. See **Field of vision**; and **Glaucoma.**

Color-field, Inversion of the. Reversal of the color-field. In hysterical visual disturbances a somewhat characteristic variation of the color-field is that the red field is the last to be affected, with the result that its extent may exceed that of the blue, and become the most peripheral of the color circles. Occasionally it is the most peripheral circle for the entire field. This is the so-called *inversion of the color-field.* Sometimes there is an excessive extent of the color-circles. Inversion of the color-field is not peculiar to hysteria; it has been observed in brain tumor, ataxia, hemorrhage in the brain, and in certain toxemias, notably those produced by lead and nitrobenzol.

Color-field of vision. The result of the examination of the color-fields depends, according to Wilbrand (*System of Diseases of the Eye,* II, p. 205), upon (1) the saturation of the color; (2) the size of the object; (3) the illumination of the object; and (4) the background (because of simultaneous contrast).

Although we find a rather broad and apparently color-blind zone between the limit of the field for white and the peripheral limit for a blue, of twenty-five square millimetres, still the periphery of the retina in its normal condition is said not to be color-blind. Donders

and Landolt have shown that the sensibility of the peripheral zone of the retina for colors would be the same as that of the centre if the intensity of the light were proportionately increased. In order to have uniformity of pigments in perimetric examinations, it has been agreed upon to use the so-called Heidelberg flower-paper. Strong diffuse daylight should always be employed.

As the quantitative sensibility for colors is greater in the adapted than in the non-adapted eye, the organ must repose before the examination of the colored fields of vision. The relation of the limits of color to the limit of the field of vision for white is of the greatest importance, inasmuch as the limit of vision for colors recedes from the limit of the field of vision for white in the order blue, red, and green, under the following conditions: in all atrophic conditions of the optic nerve and of the chiasm, and in all morbid processes resulting in pressure upon the visual fibres in the optic tract and the cerebrum. The distance between the limit for blue and that for white becoming greater, the size of all color-fields becomes smaller.

If the color-field limits be determined by the subdued light in which the field for white still proves normal, the color-field will be found to have undergone a marked degree of concentric contraction. But by using a gray test-object in strong daylight, the several fields of vision for color are obtained with their respective normal limits. The relation between the color and white limits is of diagnostic importance. If the sensibility of the retina, or, what is the same thing, the conducting ability of the optic cross-section, be assumed to be equally diminished until the white test-object in full daylight just reaches the limit of the normal field of vision, the color limits will prove to be more concentrically contracted. This is accounted for by the fact that the sensibility of the eye for colored test-objects is much less than that of the same sized white test-objects. In cases in which the color-limits are contracted and central acuteness of vision is diminished, even though a normal or slightly contracted limit for white exists, the condition is a pathological one in which progressive atrophy of the optic nerve may exist.

There are three different pathological states in which the determination of the field of vision in full daylight shows normal or almost normal limits for white, and a great reduction in its limits for colors: (1) idiopathic hemeralopia; (2) the early stage of atrophy of the optic nerve; (3) the purely functional nervous disturbances of vision. In hemeralopia color-limits contracted in daylight are perceived only at the point of fixation, and soon vanish as darkness is increased.

Concentric contraction of the field of vision for white, with a

reduction of the color-area, is pathognomonic of disturbance resulting from neurosis. There is here also a slow adaptation as compared with the normal eye.

In examining the field of vision, the *color-field* is, according to de Schweinitz (*Text-book,* p. 102), mapped in the same way that is used in ascertaining the general visual field, the squares of white in the carrier of the instrument being replaced by pieces of colored paper 1 cm. in diameter.

The order in which the colors are recognized from without inward is: (1) blue; (2) yellow; (3) orange; (4) red; (5) green; (6) violet. In practical work blue, red, and green are the colors employed, red and green being the color-sense most usually affected in pathologic cases.

Non-saturated colors are not correctly recognized when the test-object is first seen. Thus, yellow at first appears white; orange, yellow; red, brown; green, white, gray, or gray-blue; and violet, blue. The physiologic limits of the color-fields, which, like those of the general field, are subject to variations, when estimated with 1 cm. square test-object correspond closely to the following:

	Blue	Red	Green
Outward	80	65	50
Outward and upward	60	45	70
Upward	40	33	27
Upward and inward	45	30	25
Inward	45	30	25
Inward and downward	50	35	27
Downward	58	45	30
Downward and outward	75	55	45

These, when transcribed upon a chart, are represented in the figure. The numbers represent the usual limits at which the color-test 1 cm. square is recognized as such. They do not indicate its greatest intensity, which is perceived only at the fixation point. In order to avoid discrepancies, the character of the light, the nature and saturation of color, and its distance from the eye should be carefully stated in describing examinations. According to Wolffberg, the color-limits contract concentrically as the illumination is reduced, but if the photo-chemical and neuroptic apparatus is normal, there will be no change in the normal sequence of the color-limits. Blue should be employed in investigating defects in the photo-chemical apparatus, as it is the first color to disappear in reduced illumination; red suffers promptly in reduced excitability of the neuroptic apparatus.

Bordley and Cushing (*Archives of Ophthalm.,* Sept., 1909) have

shown that of 56 cases of brain tumor, in only six of these was there no disturbance of the color-fields. In forty-one out of forty-two cases examined after operation the color fields were restored to their normal relative position. It has long been supposed that reversal of the color-fields, or very marked contraction of the blue field so that it becomes smaller than the red field, is a manifestation of hysteria: It is shown in this paper that this reversal of the color-fields (dyschromatopsia) may occur as a symptom in an early stage of brain tumor. It is thought that the color disturbance in these cases is definitely

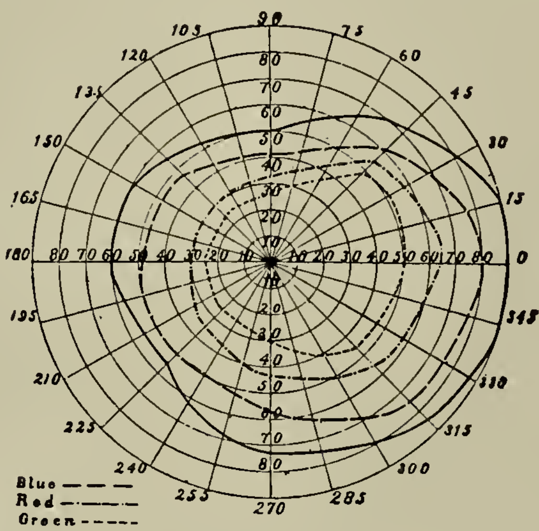


Diagram of the Field of Vision for Blue, Red and Green (de Schweinitz). The outer continuous line indicates the limit of the form field: the broken lines the limits of the color-fields.

one of the pressure symptoms and not simply a functional disturbance grafted on to an organic disease. The most prominent feature in the change of field would seem to be the limitation of the field for blue. This may take place to a varying extent so that in some cases the field for blue is entirely inside the field for red, while in other cases the fields interlace as they have also been found to do in a few cases of disseminated sclerosis in which the disease had affected the optic nerve. Occasionally relative peripheral scotomata for blue were found. Complete achromatopsia occasionally occurred. These color disturbances do not seem to be dependent upon the presence of neuroretinal edema because in four of the patients observed they preceded any appreciable ophthalmoscopic changes. It would be of great interest to know whether these four cases had suffered from temporary attacks of blindness. Some cases have been recorded in which temporary amaurosis preceded the development of any disc changes; and it seems not an improbable hypothesis that these color disturbances may in some way be related to the temporary amaurosis.—(C. P. S.)

Color-field, Reversal of. See **Color-field, Inversion of the.**

Color, Franklin's theory of. Franklin assumes that the eye, in the early periods of development, possesses only the white (or gray) visual substance and is therefore sensitive to achronatic luminosity only and not to color. Later this substance becomes modified into the blue and yellow substance, and then the yellow substance becomes modified into the red and green substance. In this way tetrachromatic sensations arise. See **Color-vision, Theories of.**

Color hearing. See **Chromatic audition.**

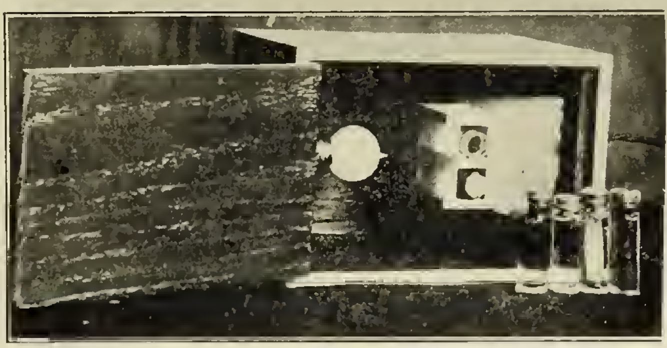
Color-ignorance. In a certain number of people there is a condition in which the peripheral and conducting parts are perfectly normal, but the central parts are not educated enough to react with the proper name for the peculiar sensation. Even this may be objectionable for certain employments. Color-ignorance can be cured by education, while true congenital color-blindness is incurable, so that a person, seeking employment, who shows simple color-ignorance in an examination may be justly re-examined.

Colori in contrasto. (It.) Contrast colors.

Colorimeter. An instrument for determining the intensity of coloration or the amount of coloring matter present in a substance.

Colorimeter, Armstrong's. This instrument, specially adapted for

Armstrong's Colorimeter (Closed). Colorimeter Closed, Showing Bottles from Anterior.



Armstrong's Colorimeter (Open). Bottles in Position, Extra Bottles, etc.

testing the excretion of phenolsulphonephthalein in the functional kidney test, was devised by Armstrong as being more practical than most of the less expensive colorimeters in general use. A two-candle-power frosted globe is used for illumination.

The standard solution is made by diluting 6 mg. of phenolsulpho-

nephthalein with one litre of distilled water and adding sufficient 25 per cent. sodium hydroxid solution to elicit the maximum color. The small bottle is filled with the standard solution, hermetically sealed and labeled 100 per cent. Serial dilutions are now made of 95, 90, 85 per cent., etc. The bottles are to be kept in a dark case and refilled when necessary. The test is carried on in the usual manner. The urine is diluted to 1 litre with distilled water, to which a 25 per cent. solution of sodium hydroxid is added to give a maximum color reaction, and a small quantity filtered. A bottle of this filtrate, the same size as that of the standard solution, is placed in one compartment, and the standard solution which matches this in the other compartment and the percentage excreted read directly.

The advantages which this colorimeter has over others are: (1) its accuracy, simplicity, and cheapness; (2) its uniform light at all times; (3) the ease with which it can be carried in case of emergency. The instrument can also be used for colorimetric determination of indican, creatinin, etc.

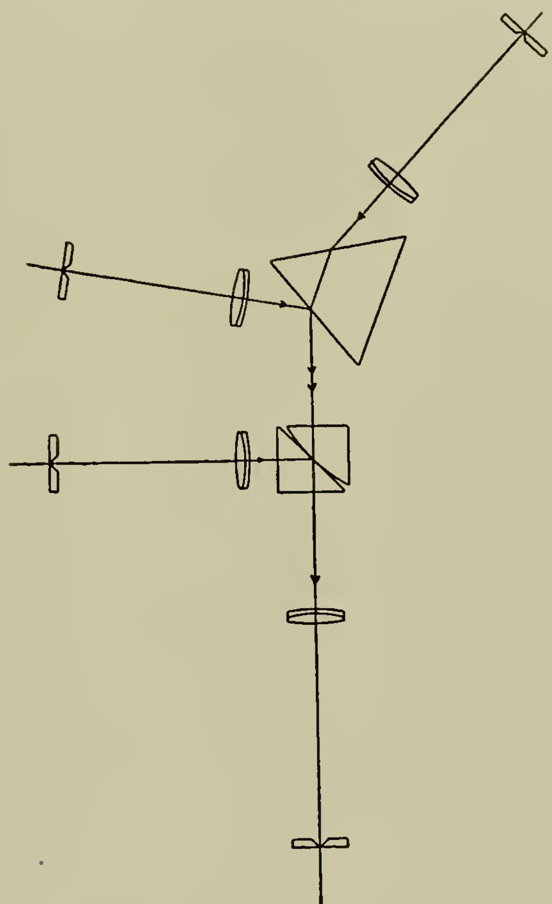
Colorimeter, Dubosey's. An instrument for determining the amount of hemoglobin in the blood by a comparison of its color with the tints of a graded series of crimson-glass plates.

Colorimeter, Ives'. In this type of colorimeter, light through three slits covered with blue, green and red glass is mixed by moving lenses, to match light directly from the unknown sample, the quantity of each primary being adjusted by varying the slit opening. The three scales each read 0 with the slit closed and 100 when open in the proportion to produce white. In the final match both color and brightness are made equal. An auxiliary white light slit permits a preliminary adjustment to equal brightness with a white unknown and each scale at 100. The instrument gives readings to from 2 to 5 per cent. under favorable conditions in the purer shades and more luminous hues, a precision barely sufficient for reproduction.

Colorimeter, Meisling's. This consists of a normal quartz plate between two nicols. As perfected by Arons (*Am. Ph.*, 33, 799-833, 1910) a set of six quartz plates $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, 4, and 8 mm. thick are used singly and in their 63 combinations, giving thicknesses from $\frac{1}{4}$ to $15\frac{3}{4}$ mm., in steps of $\frac{1}{4}$ mm. Any color is specified in terms of a thickness of quartz and an angle between nicols. The method is simple and the instrument sensitive, but subject to systematic errors due to variations in the illumination of the white comparison surface and in the direction of the light through the quartz plates.

Colorimeter, Monochromatic. This precision colorimeter was designed and is used at the Bureau of Standards, at Washington. In mono-

chromatic analyzers a variable spectral hue is mixed with a variable amount of white and the luminosity of the whole varied to match the unknown sample. Here again as in trichromatic analyzers there are three variables and their adjustment is fully as difficult. In the color triangle, instead of three coördinates these instruments determine a length and a direction out from the white centre. (See figure.)



Monochromatic Colorimeter.

Colorimetric. Color-measuring. This is generally said of methods in which the amount of a colored substance, e. g., blood, present in a given fluid is determined by comparing its color with that of a solution of the same substance which is of a known strength.

Colorimetry. The measurement of colors.

Color-induction. An optical process discovered by Brücke, and related to color-contrast. When one part of the visual field has a colored impression, and the other a colorless impression, the latter becomes covered by the (inducing) color in the (induced) colored visual field.

Color, Intensity of. The different colors of the sun's spectrum do not

appear of the same intensity. As Newton remarked, "The most luminous of the prismatic colors are the yellow and the orange—and next to these in strength are the red and green." Fraunhofer and later Vierordt were the first ones to investigate the varying intensity of the several colors. Fraunhofer compared the color of the sun's spectrum directly with colorless light. According to his results, if the intensity of yellow be placed at 1000, the intensity of the other colors will be red (B) 32, orange (C) 94, green (E) 480, blue (G) 31, and violet (H) 5.6. Vierordt determined the amount of white light which could be mixed with the several colors without producing a noticeable decrease in saturation. By this method he obtained as coefficients of intensity, red 22, orange 128, yellow 1000, green 370, blue 8, and violet 0.7. For the spectrum of a gas flame the intensities of the orange and red were greater and of the green and blue less. Rood has made an important advance in chromo-photometry by comparing the intensities of colors by means of the flickering of revolving wheels. This method obviates the difficulties in the way of the comparison of disparate sensations. When the objective intensity is altered, different colors do not maintain the same relations of brightness. It was noticed by Purkinje that if red and blue are taken, which seem to be of about the same intensity, and the illumination of each be reduced equally, the blue can be seen the longer. In general the less refrangible colors appear relatively brighter in a strong light and the more refrangible colors brighter in a faint light.

Van der Weyde and Brodhun demonstrated the fact that if a spectrum color be matched by a mixture of two colors and the intensity altered, the colors will no longer be alike. Preyer and König had previously discovered that the position of the neutral point of color-blind observers alters with the intensity. Ebbinghaus has further found that grays of the same intensity, made by combining different pairs of complementary colors, do not remain of the same intensity when the illumination of both grays is altered equally.

The alterations in color due to changing intensity greatly affect the appearance of natural objects. Increasing the intensity makes colors more yellowish, decreasing the intensity makes colors more bluish. Thus grass in the sunlight looks yellowish-green, while the part of the same plot of grass on which the shadow falls looks bluish-green. The general effect of a sunny day is yellowish, and that of a clouded day, or twilight, is bluish. A moonlight scene is still more distinctly bluish, and painters use blue tones to represent such a scene.

When the illumination is very intense or very faint, colors disappear altogether, or rather when intensely illumined they become a yellowish-white, and when faintly illumined a bluish-gray. Before colors disappear their tone is altered. Thus, if the light of the sun's spectrum be gradually diminished, the colors will disappear, except red, green, and violet-blue. These colors then become red-brown, olive-brown, and blue-gray, and finally disappear, the entire spectrum becoming gray. When the intensity is very great, violet is the first of the colors to become white, blue becomes violet, and green yellowish, before the colors disappear. Red is said to remain yellowish with the greatest intensity. In this gray spectrum the maximum of intensity is at a wave-length of $535\mu\mu$.—(C. P. S.)

Color interchanger and tester. This instrument suggests the general arrangement of a tonsillotome, the movable rod carrying at its extremity a rimless white disc and farther back the colors, red, blue and green, the latter being exposed through the circular window. Stops are provided, so that each color is properly displayed. The instrument is used in connection with the ordinary perimeter, and the ring for the thumb being revolvably mounted, any part of the arc is easily reached. The instrument may be taken apart for renewing the color discs very conveniently.

The Color Interchanger and Tester. (Meyrowitz.)

The advantages claimed for this instrument are that the entire eight readings for a full form and color field may be readily taken, checked and rechecked at each setting of the perimeter, and throughout the examination, it is not necessary to change one's position to the right or left, the measurement may be made with one hand and recorded with the other, and without interruptions ordinarily experienced in changing discs.

Color in the iris, Development of. In the development of the iris the outer layer is split off from the mesoderm of the corium of the cornea at the time of the formation of the aqueous chamber. Into this outer mesodermal layer of the iris ameboid pigment-cells proliferate after birth which are often of a different color from those that form the black epithelium of the outer cup or layer. In fact, these cells may be brown, yellow, greenish, or even brilliant red, as

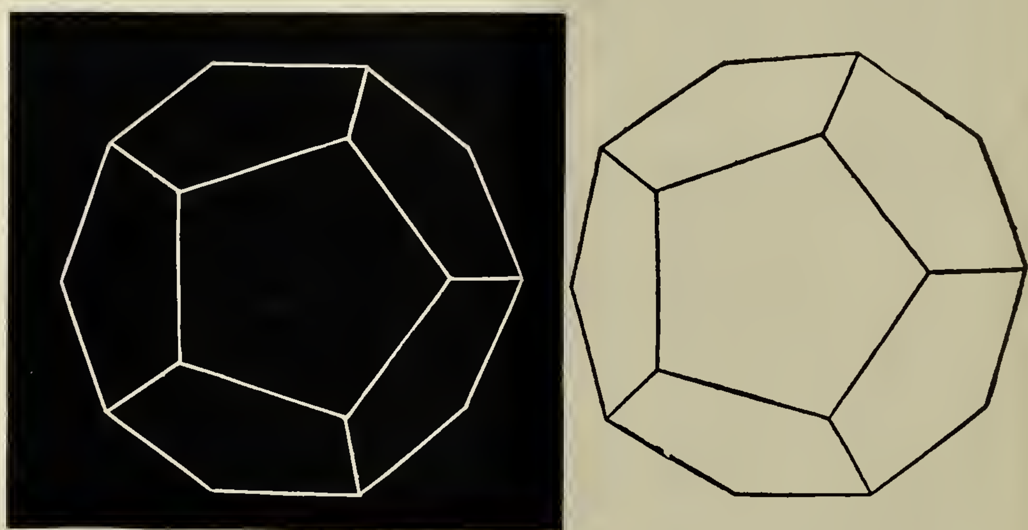
in the irides of some birds and reptiles. In man these originally ameboid pigment-cells develop after birth, and probably migrate into the outer stratum of tissue of the iris, which is of mesodermal origin, from the choroid around the edge of the iris, or become pigmented in situ as cells of mesodermal origin. These cells of various tints of brown and black give the various tints of brown, hazel, and black that are seen in the iris of the human eye.—(C. P. S.)

Coloris defectus. (L.) Color-blindness.

Color-limits, Relation of. See **Color-field of vision.**

Color measurement. See **Color standards, Universal.**

Color-mixture. Binocular color-mixture. There is quite a radical difference between the term color-mixture as used by the physicist, and as used by the painter. The term color-mixture as used by the physicist means the mixture of two color-sensations, while the painter

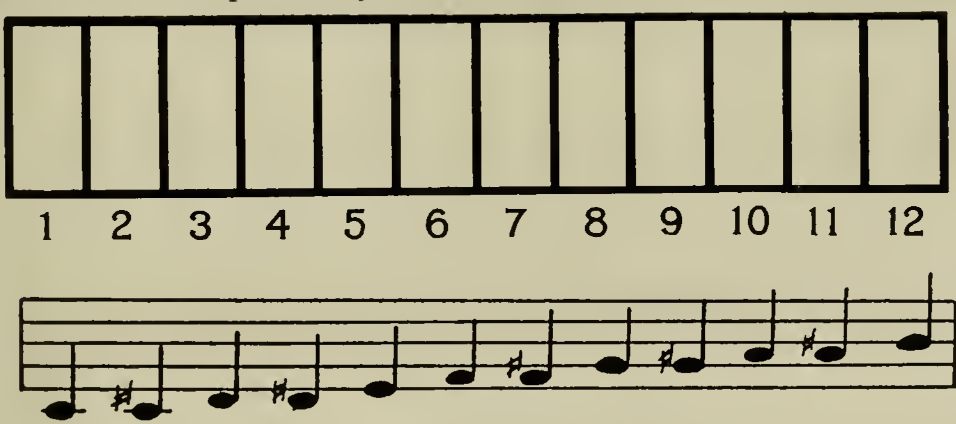


Binocular Color Mixture.
Figure for Obtaining Stereoscopic Lustre.

denotes by it their mixture of material pigments. The first refers to the addition of two sensations in our color-perceiving mind, while the second refers to the bringing together of two colored bodies which, after their mutual incorporation, do not send the two former single colors into our eye at the same time, but only a residual one, after the combined absorptive power of the two substances has done its work on the light. According to Norris and Oliver (Vol. I, p. 579), if a piece of red glass be placed before one eye, and a piece of blue glass before the other—the glasses so chosen that the object is of about the same brightness when looked at through the two glasses separately—the field of view seems at the first moment to be irregularly spotted in red and blue, the two colors appearing alternately in rivalry

over the whole field. After some time a condition of greater repose sets in, and a more or less single impression is obtained, which is considered by many physiologists to be a mixture of the two colors. That the direct color of fusion is obtained by this means is just as positively denied by others, who prove this by comparing the result directly with a mixture of the two colors brought together in the ordinary way. Numerous experiments have been devised and described in order to settle this point. Individual differences evidently play an important role in the phenomenon. This much, however, appears to have been plainly made out: the phenomenon of a fusion of colors occurs only under definite and carefully chosen conditions; it is very easily disturbed by the slightest difference in the two fields of view, which are sure to bring out rivalry; exactly the same effect as is obtained by monocular mixture of the two colors (with the color-wheel, for instance) is seldom or never produced, but rather a mixture which lies vaguely somewhere between the two. It is also of importance that the colors to be mixed should be of somewhat the same brightness, for otherwise a peculiar effect is produced. This is that of stereoscopic lustre, first discovered by Dove. A glance at the accompanying figure with an ordinary stereoscope will illustrate this.—(C. P. S.)

Color-music. The possibility of this science and art has been alluded



Chromatic Scale in Music and Color.
Showing correspondence of intervals when C equals the lowest spectrum red. 1, Deep red; 2, Crimson; 3, Orange-crimson; 4, Orange; 5, Yellow; 6, Yellow-green; 7, Green; 8, Bluish green; 9, Blue-green; 10, Indigo; 11, Deep blue; 12, Violet.

to from very early times, perhaps even prior to the Christian era. It took a somewhat tangible form in the sixteenth century in the mind of a Jesuit, Lewis Bertrand Castel. At the present time also, investigations are being carried on by scientists to attempt to establish a definite relationship between color and sound. There are many strong

points of resemblance between color and music. Briefly stated they are: 1. Color and musical sounds are both produced by vibrations acting upon the nerve terminations of the eye and ear respectively. 2. Both are limited to a certain range of visible and audible vibrations, and there are certain numerical relationships in these which may or may not be of psychological significance. 3. Both are largely dependent for their common, mental, or psychological effect upon relative degrees of harmony or discord. 4. Combinations and sequences of notes or tints in both are capable of affecting us emotionally and giving us pleasure or pain. 5. Both are capable of adding interest to and deepening or lessening mental impressions received from other sources.

Approximate ether vibrations Mil. mil. per sec.	395·0	433·0	466·0	500·0	533·0	566·0	600·0	633·0	666·0	700·0	733·0	757·0	Invisible
Approximate colour	Deep red	Crimson	Orange-crimson	Orange	Yellow	Yellow-green	Green	Bluish green	Blue-green	Indigo	Deep blue	Violet	
Musical note	(Middle) C	C♯	D	D♯	E	F	F♯	G	G♯	A	A♯	B	C_1
Vibrations per sec.	256·0	277·0	298·0	319·0	341·0	362·0	383·0	405·0	426·0	447·0	469·0	490·0	512·0

Division of Color Scale on the Keyboard of the Color-Organ, with Middle C Corresponding to the Lowest Red of Spectrum.

The most complete investigation which has been made on this subject up to the present time, is that of A. Wallace Rimington of London, and for full information on this subject the reader is referred to his book *Colour-Music, The Art of Mobile Colour,* published by the Frederick A. Stokes Company, in 1911. Rimington has constructed an instrument which he has called a *color-organ,* in which the spectrum is the analogue of the octave. (See diagrams.)

In the following table Rimington makes a comparison of visual and auditory sensations, to show some of the points of resemblance and difference between these:

COMPARATIVE TABLE OF VISUAL AND AUDITORY SENSATIONS.
Some Points of Resemblance and Difference.

VISUAL SENSATIONS.	AUDITORY SENSATIONS.
1. Physical stimulus, produced by transverse waves in the ether between the limits of 440 billion vibrations per second and 770, approximately.	1. Physical stimulus, produced by longitudinal waves in the air between limits of 20 and 22,000 per second (varies in individuals).

Change set up in the sense-organs a chemical one. The vibration-frequency of extreme violet approaches twice that of extreme red at the opposite end of the spectrum.	Change set up in the sense-organ—the basilar membrane—is probably physical. Any audible wave-frequency being doubled comprises between these extremes the musical sensations contained within the octave.
2. Hue, saturation, and intensity are dependent in the main upon wave-length, wave-complexity, and wave-amplitude respectively.	2. Pitch, timbre, and loudness are dependent in the main upon wave-length, wave-complexity, and wave-amplitude respectively.
3. A series of greys extending from white to black are due to a mixture of rays of all wave-lengths. Non-neutral greys are due to predominance of some rays of particular wave-lengths.	3. Noise, as distinguished from musical tones, probably due to a mixture of all tones. Noises may differ in pitch. This is due to predominance of certain tones.
4. From a physiological point of view well-marked turning-points in the spectrum are at yellow, green, blue, and red.	4. Salient points in the musical scale—in order of closeness of physiological relation to the fundamental tone—are octave, fifth, fourth, major third, minor third, and sixth.
5. Color mixtures or fusion of colors.	5. Combination tones, interruption tones, beats, etc.
6. Simultaneous color contrast. This occurs usually when two or more colors occupy visibly separate spaces in proximity to each other. But it may also occur when these spaces are so small as to be separately indistinguishable, as in the case of many colors in flowers or insects, or in three-color photographic processes, and this would seem to correspond to some	6. Tonal fusion, or the sensation produced by a number of notes in a united chord or noise. Ebbinghaus follows Stumpf in considering that it is a characteristic peculiarity of hearing that it is possible to distinguish individual tones in a combination—"die allgemeine Fähigkeit eine objectiv zugleich vorhandene Mehrzahl von Tönen auch

extent to tonal fusion, i. e., a number of notes combined in a chord.	subjecktiv als eine solche zŭ erkennen." But this distinction seems somewhat artificial, the real difference being that whereas the constituent tones do not occupy separate spaces, in the case of contrasting colors they must do so.
7. Successive color contrast—including "after images." (Successive contrast is an important feature of color-music.)	7. Less marked than in color, but as to "after-images" a similar effect probably occurs in the realm of sound, but of very short duration. The question has yet to be explored.

Color Non-unitary. A color-blend or non-unitary color is one in which the presence of two colors can be detected, in contra distinction to a *unitary* color, in which not the slightest trace of any other color can be seen. (Franklin.)

Color of electric lights. A series of interesting experiments has been made at the testing station of the Berlin Electricity Works, and reported by L. Bloch, to determine how nearly any sources of light approaches daylight. Any color being defined by the manner in which it is made up of the three fundamental colors—red, green, and blue; this principle is employed in these experiments, using glass of well-defined colors (red filter, green filter, and blue filter). These three colored glasses are inserted as round plates, 7 mm. in diameter and 1 mm. in thickness, in a revolvable disk in the photometer as shown in the figure, where 1 represents the red plate, 2 the green plate, and 3 the blue plate. The fourth hole is left open for making measurements in white light. Readings may be taken with any photometer. From the results of the measurement two numerical values are formed, namely, the ratio of red to green and the ratio of blue to green, corresponding to daylight with covered sky, for which both values are assumed to be 100. If the value of red to green is therefore 99.5 per cent. and that of blue to green 29.5 per cent. (which are the characteristic values for intensive flame-arc lamps with carbons giving yellow light), it means that the light of the lamp in its richness of red light agrees almost exactly with daylight, while there is a considerable lack of blue rays in the light. The author has determined these two characteristic values for all kinds

of lamps and gives the results in tables and diagrams. The magnetite-arc lamp seems to approach nearest to sunlight.—(C. P. S.)

Color of the eyes. COLOR OF THE IRIS. This subject is fully discussed by Baker in *System of Diseases of the Eye,* to which the reader is referred. The characteristic color of an eye by which it is described, is imparted by the anterior surface of the iris, being visible through the transparent cornea. This color is due partly to the dark pigmented layer of the posterior surface showing through the thin stroma, partly to pigmented cells lying in the stroma itself. When these cells are absent or nearly so, and the iris is thin, the dark background shows through the semi-opaque stroma as blue, a phenomenon caused by interference, as is the color of the cloudless sky, or the appearance of veins through a delicate skin. When the iris is thicker and the opacity greater this becomes modified to gray, and when pigment cells are scattered in considerable numbers through the stroma the color assumes various shades of green, yellow, and brown, the deepest tints of brown being the so-called black eyes.

On close inspection it will be seen that the color is by no means uniformly distributed, but appears in irregular flecks or spots alternating with lighter tints. On this account Broca advises those who wish to note with accuracy the color of the eyes to observe them at the distance of one meter, so that the tints may blend. The color is also distributed in two zones concentric with the pupil,—an inner or pupillary one, from one to two millimetres wide, darker in light eyes, and lighter in dark eyes, and an outer or ciliary one, from three to four millimetres wide, darker in dark eyes, and lighter in light ones. The distribution of the pigment varies greatly in different individuals, so much so that it has been proposed to make a systematic record of the pattern of the iris for the purpose of identifying criminals. The variations are more numerous in the ciliary zone, which may be markedly striated with radiating lines or concentric zigzags. The pigment cells may collect in spots, giving an appearance like a leopard's skin. Walker supposed these to be of a vascular character, resembling the congenital vascular tumors called nævi, and consequently named them nævi iridis. The human imagination has not neglected to exercise itself upon these flecks and markings and we consequently find that strange characters are deciphered in the eye. Lavater mentions an iris on which an ace of spades could be seen; Borelli one in which the words "Loué soit Dieu" could be read; Tenon saw the letters T and V in different cases; in others the names of Charles XII., King of Sweden, and "Napoléon, Empereur," or mystical Hebrew characters, have been found. More practical in their

bearing are those cases sometimes reported in which the deposits of pigment simulate a second pupil, or coloboma. It was noticed by Aristotle that the eyes of new-born children are almost always blue. This is due to the fact that the pigment cells of the stroma do not develop until some time after birth, the coloration not being complete until after the second year. In albinos not only is the stroma pigment wanting, but also that which lines the posterior surface. The iris consequently takes a pinkish color from the numerous blood-vessels it contains, and the eyes share with the rest of the face a deeper suffusion of color in blushing. This want of pigmentation is a serious disadvantage, as it causes great sensitiveness to a glare. Hence albinos shun bright light, and for this reason the Germans call them Kakerlakken, or cockroaches.

Considering the entire population of the world, we find that black eyes are by far the most numerous, these prevailing throughout the dark races, such as African, Indian, and Malay, and in a considerable proportion of the lighter ones, especially among peoples inhabiting tropical climates.

The color of the eyes usually corresponds with that of the hair and complexion, though not always, as it occasionally happens that blue eyes may accompany a bronzed skin, as in some Afghans (Fraser), and blue eyes and dark brown hair are not a very unusual combination. It is considered by ethnologists that a close relation between eyes and complexion is more persistent in the lower races, and that want of agreement is an indication of mixed blood.

Generally speaking, the two eyes of the same individual are the same in color, but it sometimes happens that one is blue or gray, while the other is dark. The color pales somewhat with advancing age, and may change during life as a pathological process. In an inflamed eye the iris may change from blue to yellowish-green, and if it becomes permanently thickened it may remain gray. Being very vascular, it is extremely prone to changes under inflammatory disturbances; hence a comparison of the two eyes often becomes of high importance as a diagnostic sign.

The interesting question determining the *legitimacy of an heir*, from the color of the eyes, has been studied by Kristine Bonnevie. He states (*Tidskrift f. d. n. Lägeforening*, p. 337, 1913), "If a woman with light blue or blue gray eyes has a brown eyed child, one has strong ground for presuming that the father of the child has brown or brownish eyes. We cannot, however, draw a corresponding conclusion if a brown eyed woman has a blue eyed child. The explanation is according to

Mendel's law, and is confirmed by the results of two successive investigations which also agree."—(C. P. S.)

Color of the macula lutea. Until three years ago the undisputed idea prevailed that the macula lutea during life, as well as after death, was colored yellow, and according to the explanation of Schmidt-Rimpler, one cannot see the color in the living eye because it is a "lac-dye," which appears as a somewhat darker red than the rest of the background, due to the light reflected from that part of the eye; while after death the color of all the rays of diffusion, except yellow, is absorbed, whereby the macula appears yellow.

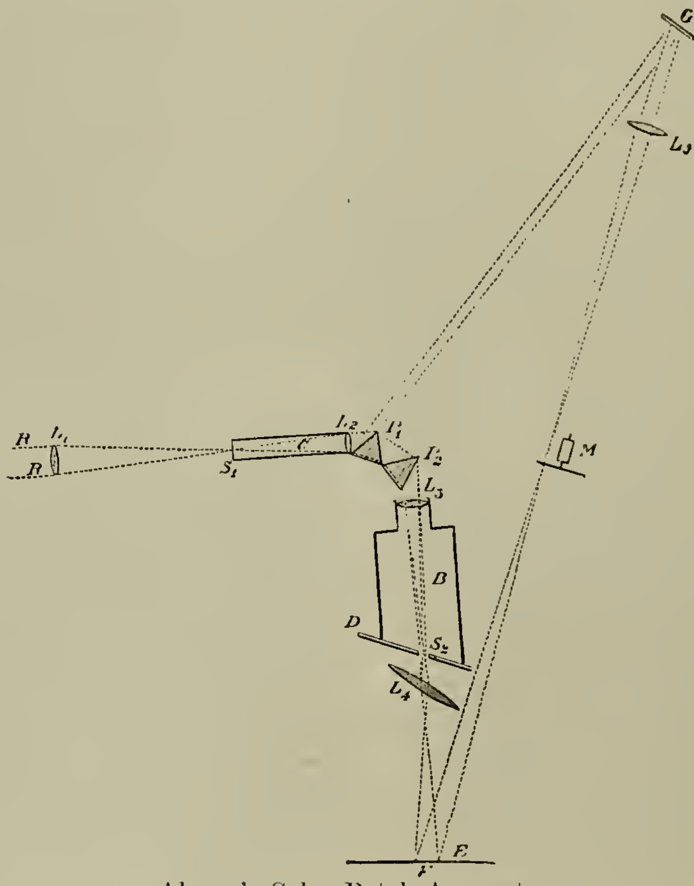
Gullstrand maintains that the yellow color is present only after death, as a result of the diffusion of the color substance; he asserts that if the Schmidt-Rimpler explanation is correct we should see the yellow color in the living eye in those cases where the light which is thrown into the eye is reflected so that the red color of the fundus is not perceived; as for example in cases of marked physiological pigmentation, where the eye ground appears a shimmering gray: here Gullstrand always saw the macula either gray or whitish. In cases of acute ischæmia of the retina, with edema, Gullstrand always noticed a red macula.

Dimmer states that in a few cases of ischæmia of the retina, he has seen the yellow color in the macula, and that in deeply pigmented persons, especially in children, the color is perceptible especially if very intense daylight is used. Gullstrand could not confirm this. Both of these men have furnished many evidences in support of their claims; ophthalmoscopic findings, the use of special light rays, entoptic appearances, examination of freshly enucleated eyes, etc. Van der Hoeve reported a patient whose eye had been injured by a cow's horn in such a way as to lacerate the optic nerve and the central retinal artery, thus cutting off the blood supply of the retina, which was of a milky-white color. The color of the macula was yellow. This was seen and confirmed by several physicians. Examination by both electric light and daylight did not produce any change from the yellow color. The color of the macula which is almost always seen in acute ischæmia of the retina is bright red, which is from the red chorioidea shining through this very thin area.

The yellow color of the macular region is accounted for by Lindsay Johnson (*"Photography in Colors"*) because of its action which is comparable to the action of the photographer's yellow color-screen, in conjunction with a color-sensitive plate, in cutting out some of the highly active blue-violet rays. If there were no pigment in the macula,

when looking at a bright white surface, we should see, not white, but blue-violet.

Color patch apparatus, Abney's. An instrument for the purpose of selecting any single color from the spectrum and throwing it upon a screen. This color, the wave-length of which is known, is used as a basis of comparison for measuring the wave-length of another color placed beside it on the screen. The apparatus and the method of using it is thus described by Abney (*Color Vision,* page 18).

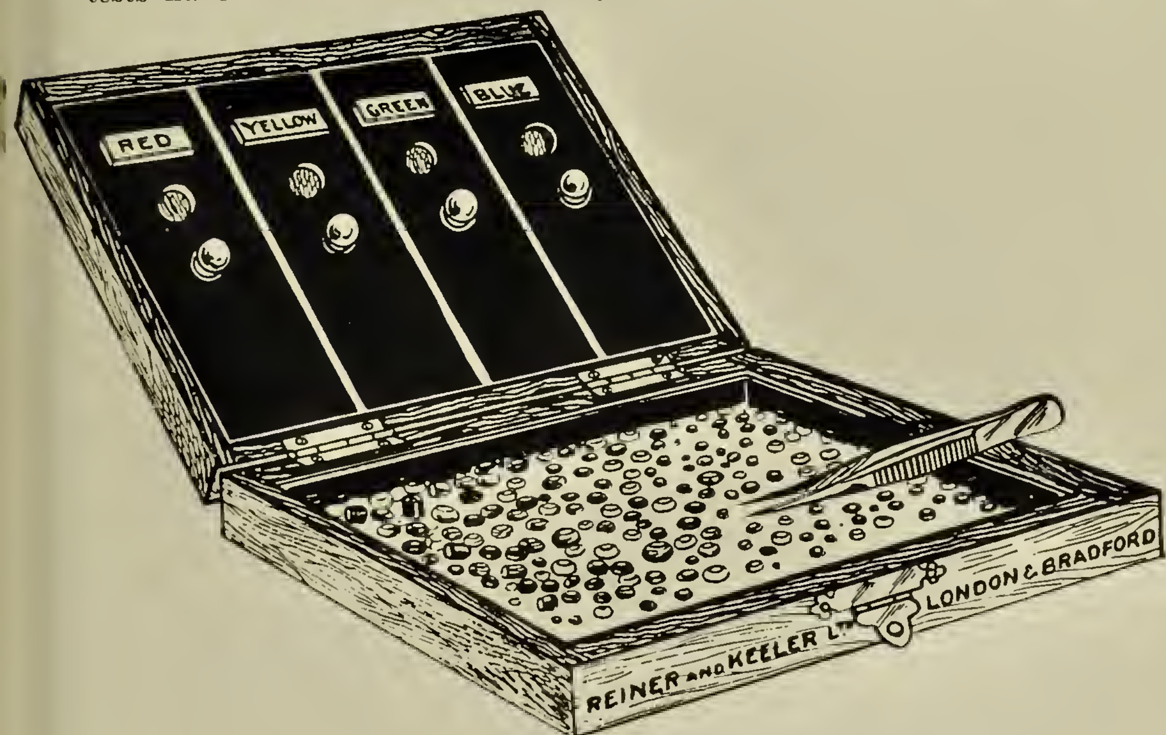


Abney's Color Patch Apparatus.

"RR are rays coming from the source of light, be it sunlight or the electric light, and an image of the one or the other is formed by a lens L_1 on the slit S_1 of the collimator C. The parallel rays produced by the lens L_2 are partially refracted and partially reflected. The former pass through the prisms P_1, P_2, and are focussed to form a spectrum at D by a lens L_3. D is a movable screen in which is an aperture S_2, the width of which can be varied as desired. The rays are again collected by a lens L_4, and form a white image of the surface of the last prism on the screen E. If the light passing through S_2 is alone used, the image at E is formed of practically monochromatic light. Part of the rays falling on P_1 are, as just said, reflected, but as it and the refracted part are portions of the light

passing through the slit S_1, they both must vary proportionally. If then we use the reflected portion as a comparison light to the spectrum colors, the relative intensities of the two, though they may vary intrinsically, will remain the same. The rays reflected from P_1 fall on G, a silver or glass mirror, and, by means of another lens L_5, also can be focussed to form a white patch on the screen E, alongside the patch of color. At M, or anywhere in the path of the beams, an electro-motor driving a sector with apertures which can be opened or closed while rotating, is placed, and the illumination of either beam can be altered at will. To obtain a large spectrum on the screen E, all that is necessary is to interpose a lens of fairly short focus in front of L_4, when a spectrum of great purity and brightness can be formed. If it be required to measure the width of the slits S_2, a small lens of short focal length placed behind L_4 and near the slit, will cast a magnified image on E, and by means of a scale placed there, the widths of each slit, if there are more than one, can be read off on the scale by bringing them successively into the same color. Originally the comparison light was a candle, and it answered its purpose fairly well, and for obtaining absolute measures is convenient at the present time. With this instrument it is easy to demonstrate that a mixed color may be mistaken for a simple color of the spectrum."—(C. P. S.)

Color-perception, Bead test for. Many forms of color perception tests have been introduced for daylight use, but some disadvantage



Bead Test for Color Perception.

has always attended their use. The bead test has been designed by Edridge-Green to provide a reliable and portable daylight test. It consists of a box divided into four compartments labelled Red, Yellow, Green and Blue. Each compartment is fitted with a lid having a hole to admit the beads. The lid of the box is lined with white opal glass, and in use forms a tray to hold a number of selected beads. These beads are selected to have the test and confusion colors necessary for Edridge-Green's particular method of testing. In use an examinee is asked to sort the beads into their respective compartments. While so doing he will make the mistakes characteristic to his order of color perception.

Color-perception, Correlative theory of. In the *American Journal of the Medical Sciences* for 1885, Oliver proposes a "correlation theory of color-perception" in which he states that "each and every healthy optic nerve filament transmits to the color-centre for recognition nerve-energies equal to as many special sensations as its peripheral tip is capable of receiving," and that "color-perception takes place through each and every optic-nerve filament." He justly lays great stress on a comparison with the sense of touch, and says, "It would be foolish to assert that there may be special division of peripheral tactile nerves especially adapted for the three empirical sensory impressions,—cold, warm, and hot." See **Color-vision, Theories of.**

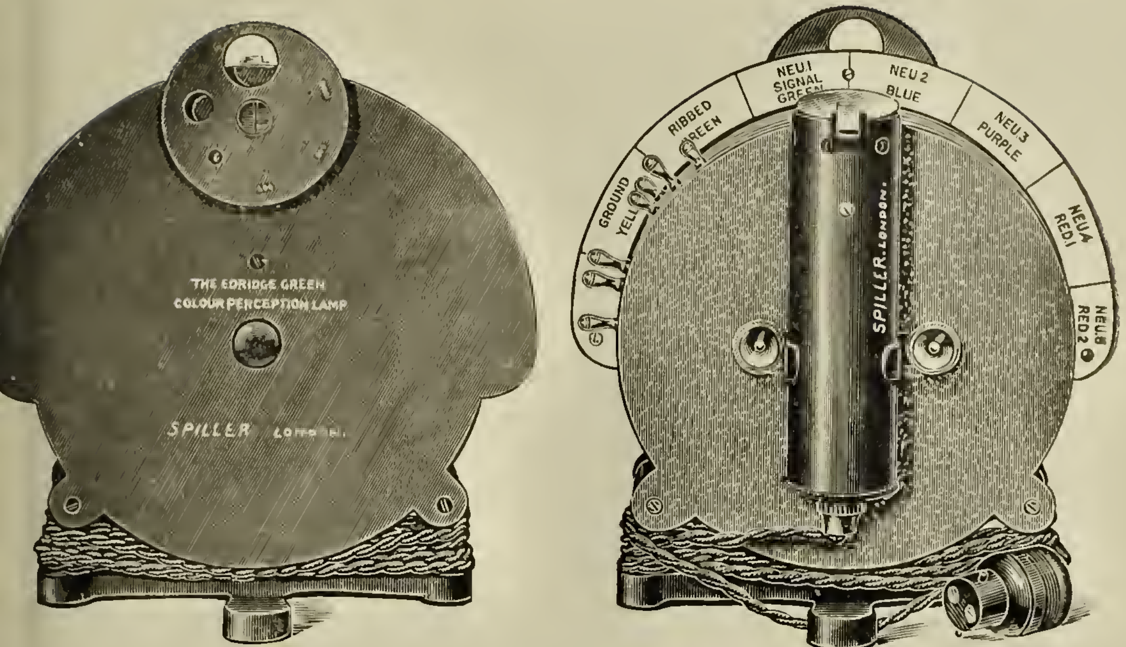
Color-perception, Ebbinghaus's theory of. See **Color-vision, Theories of.**

Color-perception, Helmholtz's theory of. See **Color-sense and color-blindness.** Also **Color-vision, Theories of.**

Color-perception, Hering's theory of. See **Color-sense and color-blindness.** Also **Color-vision, Theories of.**

Color-perception lantern, Edridge-Green's. The colors, yellow, pure green, signal green, blue, purple, red 1 and red 2, are mounted on three discs, a fourth carrying ground, ribbed and neutral tinted glasses. The discs being rotated round a common circle, the colors are brought over the illuminating lamp in succession, and various combinations may be obtained. A diaphragm, having apertures of different sizes, gives representations of railway signals or ships' lights, as seen at various distances. The lantern can be worked by means of the electric current from the mains, by a battery, or by an oil lamp.

In Williams' lantern, colored glasses are mounted in a revolving disk and the arrangement permits any of the colors to be shown singly or in pairs; for instance, a red and a green, or two reds or two greens. There is also a diaphragm for regulating the size of the opening. Each



Edridge-Green's Color Perception Lantern.

Williams' Lantern for Testing Color Vision.

of the colors is numbered, but the number is visible to the examiner only, being screened from the examined.

In the electrically lighted lantern the rheostat permits dimming of the lamps; in the oil lantern the same effect may be gotten by turning the lamps up or down. See **Color-sense and color-blindness.**

Color-perception, Normal. All those persons who can distinguish all the colors of the spectrum must be called normal with regard to color-perception. See **Color-sense and color-blindness.**

Color-perception spectrometer, Edridge-Green's. This method of spectrum analysis consists of an instrument so arranged as to make it possible to expose to view in the eyepiece the portion of a spectrum between any two desired wave-lengths. It consists of the usual parts of a prism spectroscope, i. e., a collimator with adjustable slit, prism, and telescope with eyepiece, of the following dimensions: Focal length of collimator and telescope object glasses = 7⅛″ (180 mm). Clear aperture of collimator and telescope object glasses = ⅞″ (22 mm.). Slit, 7 mm., effective length of jaw, with wedge for reducing the effective length of the slit, protective cap, comparison prism, and screw adjustment for the slit width with divided head. The prism is of flint glass, 1·65 refractive index for D. Eyepiece, Ramsden form, focussing on to the shutters described below.

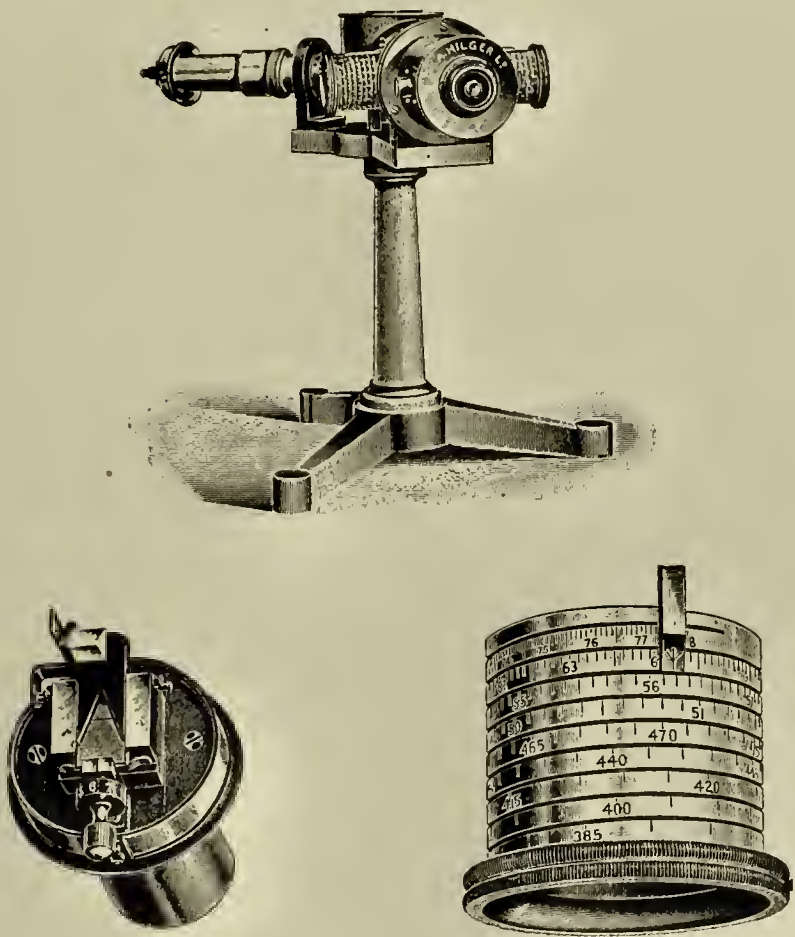
In the focal plane of the telescope are two adjustable shutters with vertical edges; the shutters being carried by levers which rotate about centres near the object glass of the telescope. The shutters can be moved into the field from right and left respectively, each by its own micrometer screw, and to each screw is attached a drum, the one being on the right and the other on the left of the telescope. On each of these drums is cut a helical slot in which runs an index, and the drum is engraved in such a manner that the reading of the index gives the position in the spectrum of the corresponding shutter in wave-lengths direct.

Thus it will be seen that if, for instance, the reading on the left drumhead is 5320 and that on the right drumhead is 5920, the region of the spectrum from wave-length 5320 to wave-length 5920 is exposed to view in the eyepiece.

An adjustment for the shutters is provided in case of possible zero alterations in course of time. These adjustments (which are provided for each shutter independently) are reached by unscrewing the small screw caps on the right and left of the eyepiece end of the telescope. This exposes a screw with a square head, on which head fits a key which is provided. To adjust either shutter the corresponding drumhead is set to the wave-length of one of the sodium lines. The slit is

illuminated by a sodium flame, and the key is turned till the edge of the shutter exactly coincides with that line. The key is then removed and the reading checked. The drum will then read correctly throughout the entire spectrum.

The instrument is used as follows:—It should be used as far as possible with a known quality and intensity of light. A small oil lamp is quite suitable for the purpose. The observer should first ascertain



Color-Perception Spectrometer. (Edridge-Green.)

the exact position of the termination of the red end of the spectrum, the left-hand shutter being moved across until every trace of red just disappears. The position of the pointer on the left-hand drum is noted, and the wave-length recorded. The left drum is then moved so that the shutter is more towards the middle of the spectrum. The right-hand drum is then moved, until the pointer indicates the wave-length recorded as the termination of the red end of the spectrum. The observer then moves the left-hand shutter in and out until he obtains the largest portion of red which appears absolutely mono-

chromatic to him, no notice being taken of variations in brightness, but only in hue.

The position of the index on the left-hand drum is recorded. The left-hand shutter is then moved more towards the violet end of the spectrum, the right-hand shutter being placed at the position previously occupied by the left-hand shutter. In this way the whole of the spectrum is traversed until the termination of the violet end of the spectrum is finally ascertained with the right-hand shutter. The variation of the size of the patches and the termination of the spectrum with different intensities of light can be noted. The instrument can also be used for ascertaining the exact position and size of the neutral patches in dichromics, the position of greatest luminosity, and the size and extent of pure colors. When it is used to test color-blindness, the examinee should first be shown some portion of the interior of the spectrum, and then asked to name the various colors which he sees. In this way he will have no clue to the colors which are being shown him.

Color-perception, Theories of. No two of these agree, and not one is entirely satisfactory. The whole question resolves itself into the fact that there is a pair of receptive elements with adaptive apparatuses capable of receiving light-rays and transferring them into energies that are carried to the occipital cortex, in which situation they are gotten ready for perception. Of the many theories advanced to explain color-perception, the ones which have received the most attention are those of Young, Helmholtz, Hering, Preyer, and Franklin. For elucidation of these see **Color-sense and color-blindness.** See, also, **Color-vision, Theories of.**

Color-perception, Variation in normal. While it has long been known that certain individuals cannot distinguish between red and green, it has been supposed until comparatively recent times that with the exception of these color-blind persons the rest of the human race could distinguish colors accurately. The experiments of Rood show that there is as much variation in all people in the power of accurate color-perception as in visual-acuity. His observations were carried out by means of the flicker photometer, for the purpose of comparing his own color-vision with that of others. He found that not a single person agreed with him, and no two agreed with each other. He later on compared his own with the color-perception of eleven persons. It was found that they could be divided into two classes according to their perception of green. The average color-vision of the eleven was taken as the normal standard, and the divergence of each person from this standard was then calculated.

Color, peripheral fields of, Perimetric test of. Examinations of the peripheral fields for color are very important in cases of acquired color-blindness, whilst they are of only scientific interest in cases of congenital color-blindness. Wm. Thomson (Norris and Oliver's *System*, Vol. II, p. 3481) advises that a perimeter be used, or if this is not available, a black-board may be taken. The patient's head is fixed, and, one eye being covered, the other is made to look at a white or gray mark in the centre of the perimeter. Little colored squares of from ten to twenty millimetres' size are moved along the black back ground of the arc of the perimeter, and the degree is marked down not only where the color is lost when moved from centre to periphery, but also where it is recognized again when brought from periphery to centre. Red and green are the most useful colors for testing the field, because it is with them that pathological defects first manifest themselves. It is also very necessary that the examiner should determine his field for the different colors on a normal person under the same conditions, because the pigments of the same name are by no means all alike, nor is the illumination always the same. Thus he will be better able to eliminate the accidental factors and obtain results that will allow accurate deductions.—(C. P. S.)

Color phenomena of contrast. Our judgment of colors is always influenced by the colors of surrounding objects. This fact is well known to painters, whose color-sense is generally highly developed, so that they often see colors that inexperienced persons would not perceive. But in special circumstances, this influence makes itself felt in a very striking manner. See **Color-sense and color-blindness.**

Color phenomena, Prismatic. The color-phenomena attending the use of prismatic glasses are easily understood. One may imagine every object in the field made up of the three layers of Young-Helmholtz primaries, and that in any change of outline due to distortion or displacement, the violet is moved a little more, while the red is moved a little less, than the green, the result being that uniform surfaces are unchanged in hue, but that outlines of light surfaces on the side towards which the displacement is effected are fringed with violet, and those opposite are fringed with red.

Color photography. Seebeck of Jena in 1810 described the impression he obtained on paper impregnated with moist silver chloride. This is the first recorded instance of colored light impressing its own colors on a sensitive surface. In 1839 Sir J. Herschel (*Athenæum*, No. 621) gave a somewhat similar description. In 1848 Edmond Becquerel succeeded in reproducing upon a daguerreotype plate not only the colors of the spectrum, but also, up to a certain point, the colors of

drawings and objects. Poitevin obtained colored images on ordinary silver chloride paper by preparing it in the usual manner and washing it and exposing it to light. It was afterwards treated with a solution of potassium bichromate and cupric sulphate, and dried in darkness. Sheets so prepared gave colored images from colored pictures, which he stated could be fixed by sulphuric acid. St. Florent, in 1874, immersed ordinary or albuminized paper in silver nitrate and afterwards plunged it into a solution of uranium nitrate and zinc chloride acidulated with hydrochloric acid; it was then exposed to light till it took a violet, blue, or lavender tint. Before exposure the paper was floated on a solution of mercuric nitrate, its surface dried, and exposed to a colored image.

In 1880 Abney showed that the production of color really resulted from the oxidation of the chloride that was colored by light. Plates immersed in a solution of hydrogen peroxide took the colors of the spectrum much more rapidly than when not immersed, and the size of the molecules seemed to regulate the color.

In 1841 Robert Hunt published some results of color photography by means of silver fluoride. Turner thus describes a method, devised by Gabrielle Lippmann, of Paris, by which the natural colors of objects are reproduced by means of interference: "A sensitive plate is placed in contact with a film of mercury, and the exposure to the spectrum, or to the image of colored objects to be photographed, is made through the back of the plate. On development, the image appears colored when viewed at one particular angle, the colors being approximately those of the object. The necessary exposure to produce this result was very prolonged in the first experiments in which the spectrum was photographed, and a longer exposure had to be given to the red than was required for the blue. Lippmann at first employed collodion dry plates, prepared, it is believed, with albumen, and it required considerable manipulation to bring out the colors correctly."—(C. P. S.)

Color protection from light and heat. It is reported by Hans Aron in the Philippine *Journal of Science* that certain monkeys are killed by two hours of exposure to the tropical sun. Considering that monkeys are almost exclusively of tropical habitat, this is certainly astonishing; but the explanation is doubtless found in the fact that the natural home of the monkey is the forest, where protection from the sun can always be secured. It is reported that rabbits likewise succumb rapidly to the effects of direct exposure to the tropical sun.

Doubtless both these animals have failed to develop a capacity for heat-regulation because their habits of life do not normally subject

them persistently to the sun's direct influence. Animals that are brought habitually into the sunlight have developed a perspiratory apparatus that serves the purpose of rapidly eliminating heat from the body. In the case of human races the same thing is observed, it being known, for example, that the colored races perspire more freely than white races.

About a quarter of a century ago Robert Wallace, of Edinburgh, pointed out the striking fact that the domesticated animals of the tropics have black skins. Biologists now explain this curious phenomenon as due to the fact that the pigmented skin gives protection from the lights, and prevents injury to the subcutaneous tissues through the influences of ultra-violet light-rays. Charles E. Woodruff, whose researches in this field are well known, believes that agricultural experimenters have failed to establish the big white swine in our West or in any light climate, and that farmers in many parts of the world are vainly trying to breed imported stock that is insufficiently pigmented. He suggests that recognition of the principle that an animal subjected to bright light must have the protection of a pigmented skin would be of great practieal importance in preventing the present wasteful method of stock-raising.

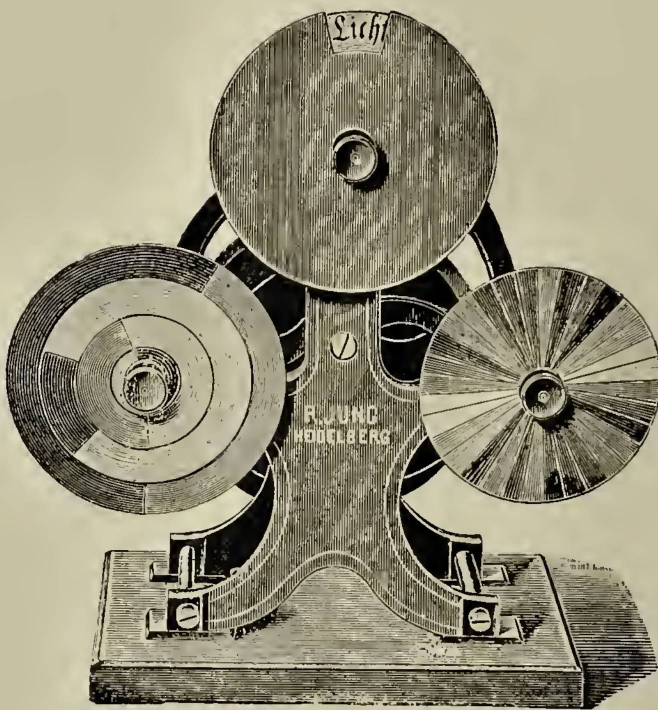
The pigmented skin, it should be observed, is not an unmixed blessing to the animal of tropieal climates, inasmuch as the dark skin absorbs heat more rapidly than the light one. But it also radiates heat more rapidly, so the dark animal placed in an atmosphere slightly below the body temperature keeps cooler than the light animal under similar eircumstanees. Thus it is that the dark-skinned animals of the tropics instinctively hide in the day, unless the skin is eovered by a reflecting eoat as in the case of the Arab horse. See, also, **Light, Effects of, on the eye and human organism.**

Color-rotation apparatus of Jung. This is a modified Newton color-disc, designed to show the method of producing different color combinations by means of the rapid rotation of the discs. The apparatus, mounted upon an oak base, is supplied with color discs of different patterns. The discs are made to revolve by means of electricity, making it much easier to demonstrate single color-appearances, eomplementary eolors, etc., than when rotated by hand. (See next page.)

Colors, Accidental. Complementary eolors, i. e., any color that added to another color or to a mixture of colors, produces white.

Colors, Canonical. Ecclesiastical colors. Liturgical colors. Colors employed for specified symbolical purposes in vestments and hangings. See **Colors, Symbolism of.**

Color-scotoma, Test for central. In testing for a central color-scotoma, the patient's head is fixed before the perimeter, and, one eye being covered, the other is made to look at the white mark in the centre of the perimeter. Smaller squares should be used than the ones used to determine the white field: from one to ten millimeters' size are taken. They are first carried to either side, and finally on the point of fixation, when in the presence of a marked scotoma the color will be recognized to one or both sides, but not in the very centre. If the defect is only partial, the color will appear not so bright at the point of fixation as to the side of it, for which examination in such a case



Jung's Color Rotation Apparatus.

very light shades of red or green must be taken. The limits of the scotoma may be mapped out in the same way, if the squares are not too large nor their shades too bright.—(C. P. S.)

In 1893 Holth (*Annales d'Ocul*, Sept., 1908) observed Bjerrum detect the scotoma in a case of tobacco amblyopia in the following way. The patient was placed with his back to the light and fixed with one eye the top button of the observer's waistcoat, on each side of which was a red disc of 3 cm. diameter. These discs were of equal color, but to the patient the one on the temporal side appeared paler than that on the nasal, because its image fell on the affected part of the retina. The method seemed to Holth to be a practical one, and it was found to be so in patients whose visual acuity did not exceed $\frac{5}{20}$: above this, smaller test objects were necessary. For these the

author used the rose-red ends of certain Norwegian matches—by soaking the heads of these in water the white salts were removed and a uniform rose tint obtained. The matches were stuck into the end of the box, the middle one being vertical the two lateral obliquely inclined and so arranged that the heads were all in the same horizontal line. The patient fixes the central match head and is asked concerning the color of the other two.

In order to avoid the trouble of preparing the matches and fixing up the little apparatus each time it was needed, the author has had a permanent one made upon similar lines. This consists of a bar of ebonite, 16 cm. long by 2 broad, and 4 mm. thick; on each of the faces small circular pits 1 mm. deep are drilled. On one face these are 5 mm. diameter and on the other 10 mm., the distance between them being 4 cm. on each face. The pits are filled with rose-colored wax finished off flush with the surface. In using the instrument it is held horizontally 30 cm. from the patient, parallel with the window—which is directly behind him. The upper border is slightly inclined forwards so as to avoid reflection. The patient fixes the central disc. In tobacco amblyopia the temporal disc is always altered in color, being washed out—or perhaps discolored. The test is extremely sensitive and has given positive results even in cases where the visual acuity was as high as $5/10$ to $5/6$. When the scotoma is absolutely central the central disc is the palest of the three, the others preserve their color. The central object also becomes pale in advanced paracentral scotoma of tobacco amblyopia.

It is to be observed that this method of detecting scotomata is only applicable to those cases which owe their origin to a toxic or infectious neuritis. The small irregular paracentral scotomata of macular choroiditis, hemorrhages, or other lesions, are more easily detected by perimetry with small test objects at 1 or 2 metres (Bjerrum), or by the stereoscopic method. (*Ophth. Review,* Sept., 1909.)

Color scotometer, Cruise's central. This device is for testing for defects of color vision in the central field, as found in the toxic amblyopias. The colors are seen against a white background, and a sliding diaphragm permits the observed color to be viewed through an aperture of 8 mm. or 4 mm. A milled disc revolves the colors successively into position, and a corresponding color on the back of the disc denotes to the surgeon the color under observation. A pupilometer is inserted at the top of the instrument.

Color-screen. RAY-FILTER. A body, either liquid or solid, that cuts out or reduces the light-waves at one or both ends of the spectrum. The filter or screen is so placed that all rays finally reaching the objective

must pass through the screen. Color-screens are much used in photography in all its branches. The most generally used screen is a solution of dichromate of potash, which cuts off the violet, the blue, and the bluish-green rays. See **Color-photography.**

Color-sensation. By the simultaneous effect of different simple colors on the same spot of the retina, there is produced a color sensation, such a color not existing in nature, and there being no part of the spectrum in which the wave-length would produce this color. Thus, purple is a color-sensation, produced by a mixture of violet or blue with red, and it seems to form for our eye a bridge between the red and the violet and the red of the spectrum. And still purple does not exist as such in nature, and there is no part of the spectrum in which the wave-length is such that the corresponding color will be purple.—(C. P. S.) See **Color-sense and color-blindness.**

Color-sense. This is one of the subdivisions of the sense of sight. It is the power which the retina has of perceiving color; or it may be defined as that sensation which results from the impression of light-waves having a certain refrangibility. See **Color-sense and color-blindness.**

Color-sense and color-blindness. Since color possesses no tangible physical properties, but is purely a sensation, any description or definition of color-sense is largely theoretical.

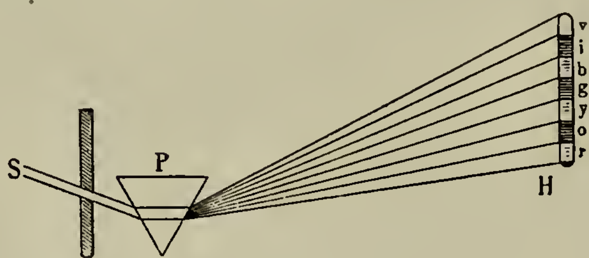


Diagram Illustrating the Decomposition of White Light and Formation of the Solar Spectrum.

The first authentic attempt to describe and class the phenomena of color was made by Theophrastus at a period a little earlier than 300 B. C. In modern times, Robert Boyle, the English philosopher, in 1663 wrote a treatise on colors. He was followed by Sir Isaac Newton, who in 1672 published in the *Philosophical Transactions* his various optical theories. The next writing of any importance on this subject is Goethe's celebrated *"Farbenlehre"* published in 1810. Goethe violently opposed Newton's color theories.

Color has been described as a special sensation excited by the action on the retina of rays of light of a definite wave-length. On the most likely hypothesis as to the physical nature of light, color

depends on the rate of vibration of the luminiferous ether. White light, as first shown by Newton, can be decomposed by a prism into the spectral colors red, orange, yellow, green, blue, indigo, and violet; the colors appearing in this order and passing gradually into each other without abrupt transitions.

The discovery and explanation of the fact that the light of the sun is composite and consists of light of a great variety of colors, is unquestionably the greatest of Newton's contributions to optical science. Admitting the rays of the sun through a small circular opening in the window-shutter, Newton caused these rays to pass through a glass prism, and was surprised to find that the image on the opposite

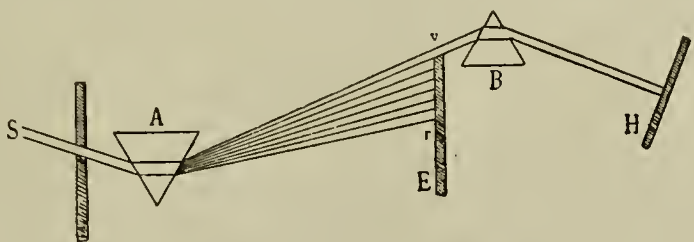


Diagram Illustrating the Impossibility of Further Decomposing Spectral Rays.

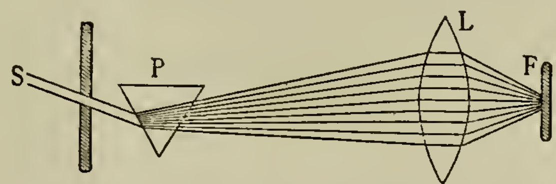


Diagram Illustrating the Recomposition of White Light.

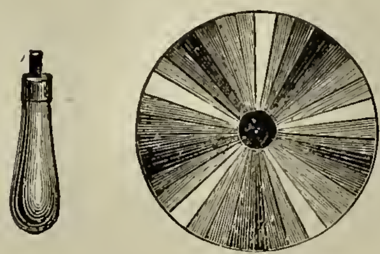
wall, instead of being a circular spot of white light (as was produced before the interposition of the prism in the path of the beam) was an elongated spectrum, with vivid colors, and about five times as long as it was broad. He was led to conclude that sun-light is not homogeneous, but is composed of rays of different colors, some of which are more refrangible than others, the red rays being the least refracted and the violet rays the most refracted; so that the colored spectrum varied by imperceptible gradations of color from red at one end to violet at the other.

The spectral rays, moreover, are *saturated* or *simple* colors: that is, they cannot be further decomposed by a prism. For example, if all the rays of the spectrum, except the violet, be intercepted by means of a screen (E, in the figure) and if the violet rays be made to pass through a second prism, refraction takes place, but the light received on the screen (H) remains unchanged.

Inversely, white light which has been decomposed by a prism into the various colors of the spectrum, may be reproduced by combining

the colored rays. If the spectrum be allowed to fall upon a double-convex lens (see figure), the rays are reunited to form a pencil of white light on the screen (F) placed at the focus of the lens.

By means of Newton's disc it can be shown that white light can be produced from a combination of the spectral colors. The disc is made of card-board about one foot in diameter, upon which is pasted strips of colored paper to represent five spectral colors; the centre is covered with black paper. (See figure.) If the disc be made to rotate rapidly the retina receives the impression of white (gray). This will not be a pure white because pigment colors are not pure, and because it is difficult to arrange the colors in the same proportion as they exist in the spectrum.



Newton's Disc.

White is therefore not a simple color, but it is a compound of all the colors in definite proportion. It is merely the color of sunlight. All the visible pure colors as thus defined are to be found in the spectrum, and there is an infinite number of them, corresponding to all the possible variations of wave-lengths within the limits of the visible spectrum. Thus 6562 ten-millionths of a millimetre produces to most of us a red color in the spectrum. (See figure.)

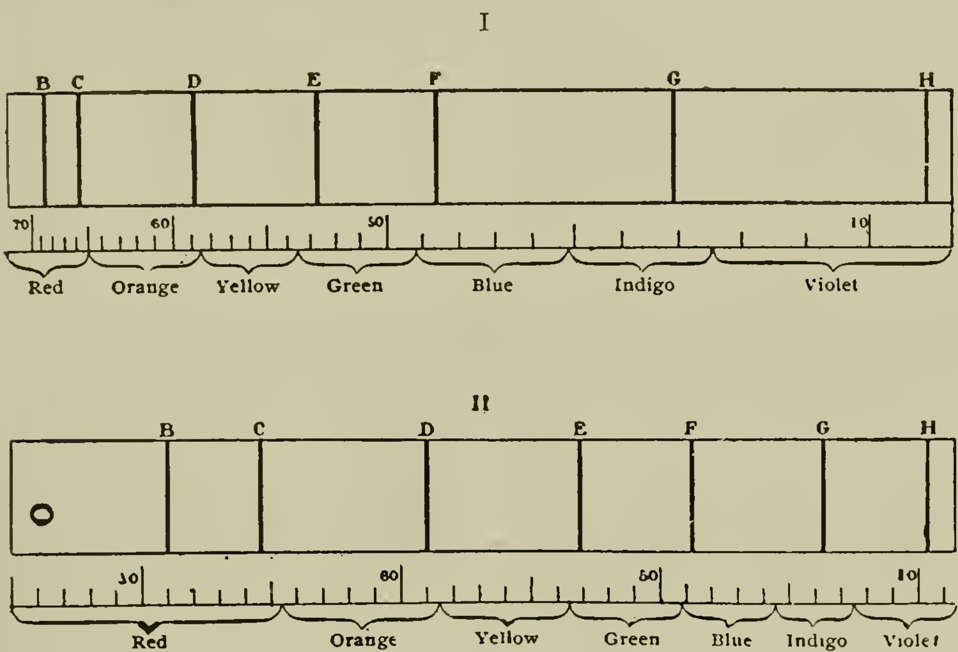
Table of wave-lengths in ten-millionths of a millimetre:

Deep red	6866	Bluish green	4861
Cherry red	6705	Blue	4603
Red	6562	Violet	4307
Orange	5892	Extreme violet	3968
Green	5269		

We have thus a scale of light of different wave-lengths which we can apply to the study of the sensations stimulated in the eye, and so have the means of instituting a comparison between the color-vision of different eyes. A mixed or composite color is in a different category, however, to the simple colors. It is one which may be formed by any number of rays of different wave-lengths falling on the eye. What these rays are we can only tell by analyzing the light and referring them to the spectrum. On this view there is a strict

analogy between variations of *color* in light, and variations of *pitch* in sound. But the visible spectrum contains a range of frequency extending over about one octave only, whereas the range of audibility embraces about eleven octaves. (See the illustration.)

The original investigators in color phenomena were the artists, and they found that neither red nor yellow nor blue could be formed by any mixture of pigments on their palette, but that all other colors could be made by a mixture of two or more of these three. Hence to these three were given the name of primary colors. When, however,



I. Spectrum of Refraction. II. Spectrum of Diffraction. The Numbers Indicate the Wave Length in Hundredths of mm.

the physicist began to work with the simple colors of the spectrum, it was speedily found that, at all events, the yellow was not a primary color, as it could be formed by a mixture of red and green, while a green could not be formed by a mixture of any other two colors. A primary color can therefore be defined as one which cannot be formed by the mixture of any two or more colors. Let us take three discs, a red, a green, and a blue, matching them as closely as possible with the red, the green, and the blue of the spectrum. By having a radial slit cut to the centre of these card discs, we can slip one over the other so as to expose all three colors as sectors of a single disc. Then we can place the compound disc on the axis of a rapidly rotating motor and the colors will blend together giving a uniform color. Any proportions of the three colors can thus be mixed, and by a judicious

alteration in them, we can have them so arranged as to produce a gray. By interlocking together (see figure) a black disc and a white disc, each with a diameter slightly larger than that of the other discs, but equal to each other, and rotating them on the same spindle behind the three color discs, we can, by an alteration in the proportion of black to white, form a gray which will match that produced by the rotation of the three colored sectors. In other words, white, though degraded in tone, can be produced by the three complex pigment colors, as we have seen can also be done by the mixture of the three simple spectrum colors. The mixture of the three spectrum colors can match other colors than white. For instance, it can be made to match the color of brown paper. With the color discs we can also do exactly the same by introducing if necessary, a small quantity of white or black, or both, to dilute the color or to darken its tone. Another application of the same principles enables us to produce an artificial spectrum by means of a red, a green, and a blue glass. By fixing

Color Discs.

these three glasses behind properly-shaped apertures cut in a card disc at proper radial distances from the centre, and rotating the disc, we have upon the screen, when light is passed through them, a ring of rainbow colors. If the beam of light be first passed through a suitable rectangular aperture, the breadth of which is small compared with its length, placed close to the rotating disc, and an image of the aperture be focused on the screen by a suitable lens, we shall have a very fair representation of the spectrum, every color intermediate between the red and green, or the green and blue, being formed by mixtures of these pairs, respectively. This furnishes a very fair proof that vision is really trichromic—that is, that it is unnecessary to have more than the sensations of three colors to produce the sensation of any of the others.

The colors of the various objects which we see around us are not due (with the exception of self-luminous and fluorescent bodies) to any power possessed by these objects of creating the colors which they exhibit, but merely to the exercise of a selective action on the light of the sun, some of the constituent rays of the white light with which they are illuminated being absorbed, while the rest are reflected, or

scattered in all directions, or in the case of transparent bodies, transmitted. White light is thus the basis of all other colors, which are derived from it, by the suppression of some one or more of its parts. A red flower, for instance, absorbs the blue and green rays, and most of the yellow, while the red rays, and usually some yellow rays are scattered. If a red poppy is illuminated successively by red, yellow, green and blue light, it will appear a brilliant red in the red light, yellow in the yellow light, but less brilliant if the red color is pure; and black in the other colors, the blackness being due to the almost complete absorption of the corresponding color. If a surface absorbs all the light so as to reflect nothing, it appears to be black. If a body held between the eye and the sun transmits light unchanged and is transparent, it is colorless, but if translucent it is white. If the medium transmits or reflects some rays and absorbs others, it is colored. Thus if a body absorbs all the rays of the spectrum but those which cause the sensation of green, we say the body is green in color, but this green can only be perceived if the rays of light falling on the body contain rays having the special rate of vibration required for this special color. For if the surface be illuminated by any other pure ray of the spectrum, say red, these red rays will be absorbed and the body will appear to be black. As a white surface reflects all the rays, in red light it will appear to be red, and in a green light, green. Color, therefore, depends on the nature of the body, and on the nature of the light falling on it, and a *sensation of color* arises when the body reflects or transmits the special rays to the eye.

In the higher visual cortex on the postero-lateral aspect of the cerebral hemispheres, the temporo-occipital or fusiform lobes are devoted to the recognition of colors. The isolated position of the fusiform lobe renders it probable that when a lesion is a primary one in that part of the occipital lobe, the earliest symptoms would be confined to loss of color-sense. On the other hand, a lesion spreading from other parts of the visual area would probably render the patient blind before a diagnosis of loss of color recognition could be made. A lesion confined to both fusiform lobes would probably not interfere materially with form vision, the centre for which is farther back, except that the negation of color would tend to blend all objects in one harmonious tint. Such was the vision of our ancestors some few thousand years ago. In the present day, however, a congenital case of total color-blindness is rare, and still fewer acquired cases have been published. A one-sided lesion in the color centre is occasionally met with, and probably they are more common than is acknowledged.

A patient so affected, in walking along a country lane, would have a green hedge on one side and a gray one on the other.

It is well recognized that there are symptoms which point to intracranial pressure which precede papillœdema, and amongst these are changes in the recognition of color. The importance of these prepapillœdematous symptoms lies in the fact that the tendency of present-day surgery is in the direction of early decompression operations.

What now is the mechanism of color sensation and color blindness? Various theories have from time to time been advanced to explain these phenomena, and while each has its adherents it must be admitted that no one of them is absolutely satisfactory, as none of them fully explains the phenomena in question. Thomas Young, the physicist, was the first one to propound a really philosophical theory of the subject, in 1807. He supposed that the retina contained three sets of color-perceiving elements, corresponding to the fundamental colors,

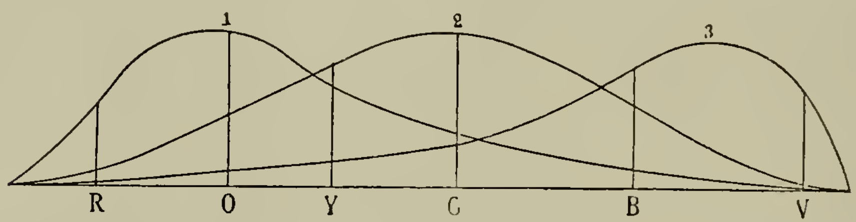


Figure to Illustrate the Young-Helmholtz Theory of Color-Perception.

red, green, and violet, and that all other colors were varying mixtures of the fundamental sensations. Helmholtz modified this hypothesis by suggesting that every kind of light excites the red, green, and violet perceptive elements at the same time, but with different degrees of intensity. (See fig.) The three curves represent the excitability of the red, green, and violet perceptive elements to solar light; the colors of the spectrum are placed along the horizontal line, beginning with red (R) and ending with violet (V). It is thus seen that the pure red of the spectrum strongly excites the retinal elements sensitive to red, to a less degree the elements to green, and still less the elements sensitive to violet. We thus get a sensation of red because the elements reacting to red receive the greatest excitation. Orange light strongly excites the elements sensitive to red and to a less degree the green; resulting sensation, orange. Pure yellow light strongly excites the elements sensitive to red and green, while having little action on the elements sensitive to violet. From this almost equal mixture of red and green arises the sensation of yellow. Green light strongly excites the elements sensitive to green, and about equally, but to a much less degree, the elements sensitive to red and

violet; hence the sensation of green. Pure blue light strongly excites the elements sensitive to green and violet, and but slightly the elements sensitive to red; resulting sensation, blue. Violet light strongly excites the elements sensitive to violet, and has but little action on the red and green elements; hence the sensation of violet. When the elements sensitive to red, green, and violet are excited simultaneously to the same degree, the resulting sensation is white. A glance at the figure shows that no color of the spectrum is fully saturated, for the reason that it always contains more or less of the other two primary colors. Yellow and blue are the most luminous colors of the spectrum, because the elements of two of the primary colors are excited to a high degree, while the elements sensitive to the other are excited to a considerable degree.

Red-blindness. According to the Young-Helmholtz theory, blindness to red is due to the absence or paralysis of the organs perceiving red. (See figure.) Red-blindness has then but two fundamental col-

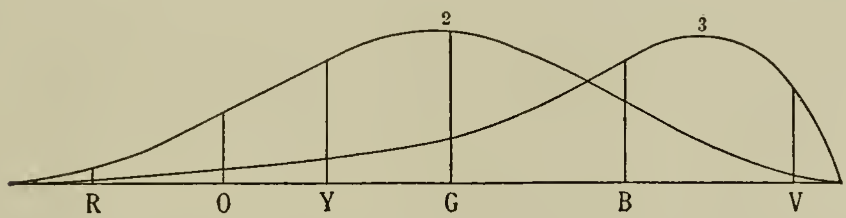


Figure to Illustrate Red-blindness, according to the Young-Helmholtz Theory.

ors—green and violet. According to Helmholtz, spectral red, which feebly excites the perceptive organs of green and scarcely at all those of violet, must consequently appear to the red-blind, a saturated green of a feeble intensity, more saturated than normal green, into which a sensible portion of the other primitive colors enters. Feebly-luminous red, which affects the perceptive organs of red in a normal eye sufficiently, does not, on the other hand, sufficiently excite the perceptive organs of green in the red-blind, and it, therefore, seems to them black. Spectral yellow seems to them a green saturated and intensely luminous, and, as it constitutes the precisely saturated and very intense shade of that color, it can be understood how the red-blind select the name of that color and call all those tints that are properly speaking green, yellow. Green shows, as compared with the preceding colors, a more sensible addition of the other primitive colors; it then appears, consequently, like a more intense but whitish shade of the same color as yellow and red. The greatest intensity of light in the spectrum, according to Seebeck's observations, does not appear to the red-blind to be in the yellow region, as it does to the normal eye,

but rather in that of the blue-green. In reality if the excitation of the perceptive organs of green, as it was necessary to assume, is strongest for green, the maximum of the total excitation of the red-blind, must be found slightly toward the blue side, because the excitation of the organ perceiving violet is then increased. The white of the red-blind is naturally a combination of their two primitive colors in a determinate proportion—a combination which appears blue-gray to the normal sight; this is why they regard as gray the spectral transition colors from green to blue. Then the other colors of the spectrum, which they call blue, preponderates, because indigo-blue, though somewhat whitish according to their chromatic sense, is to them, owing to its intensity, a more evident representative of that color than violet. According to this theory then, it is clear that one who is red-blind cannot distinguish red from green, because these colors excite the same elements.

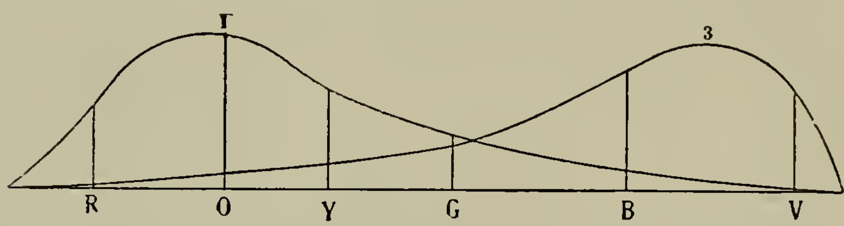


Figure to Illustrate Green-blindness, according to the Young-Helmholtz Theory.

Green-blindness. According to the theory, blindness to green is due to the absence or paralysis of the organs perceiving green (see figure). The green-blind has therefore but two fundamental colors: that is, red and violet. According to Holmgren, "The spectral red, which strongly excites the perceptive organs of red, and but very faintly those of violet, must therefore appear to the green-blind as an extremely saturated red, but of a light, somewhat less intense than the normal red, which is comparatively more yellowish, as green forms a part of it. The spectral orange is again a very saturated red, but on the other hand, more whitish, because a sensible portion of the other primitive colors enters into it. Green, with its shades inclining to yellow and blue, ought, correctly speaking, to be a saturated purple and with a mean intensity of light; but it is the white (gray) of the green-blind, for it is composed of almost equal parts of the two primitive colors. The blue is an intense violet, but a little less saturated than indigo, which is more strongly luminous and more saturated. Violet is a little less intense, but more saturated than normal violet. The tints most luminous and at the same time most saturated, which must constitute the types of the primitive colors of

the green-blind, are orange or its immediate neighbor in the spectrum (red) and indigo-blue. Now, orange is a color which, in ordinary language, especially among the uncultivated and unpractical, is indiscriminately called red and yellow; this fact explains why the green-blind denominate their first fundamental color sometimes *red* and sometimes *yellow*. In green-blindness the same organ is also found affected by spectral red and green light. Red and green are then perceived by the green-blind in the same way, or, in other words, are to them, in fact, exactly the same color. In cases where they succeed in distinguishing them, it is by the aid of the intensity of the light; but the opposite of what occurs in the case of the red-blind. A green tint, which to the green-blind must appear exactly like a red one, to a normal sense of color must be sensibly more luminous than red."

Violet-blindness. This form of color-blindness, according to this theory "is due to the absence or paralysis of the elements perceiving violet (see figure). The two primitive colors of the violet-blind are

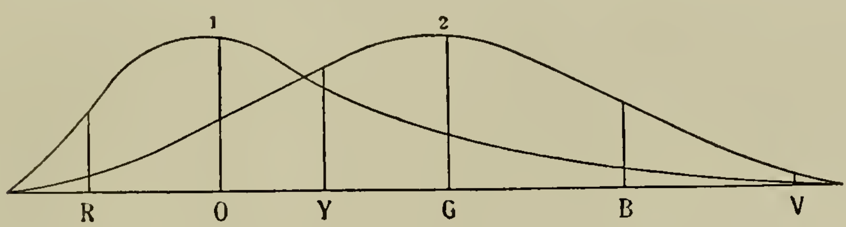


Figure to Illustrate Violet-blindness, According to the Young-Helmholtz Theory.

then red and green. The red is a purer red color (not yellowish) than normal red, but still less saturated; the more it inclines toward orange the more strongly luminous it is, but is at the same time less saturated, more whitish. The yellow is, as it were, a combination of almost equal proportions of the fundamental colors that form white. Green is a strongly luminous, but whitish, green, which intending toward blue, becomes more and more saturated; so that greenish blue must be the type of these hues. The blue is a green of moderate luminosity and strongly saturated, and violet is a green very feebly luminous, but also saturated in a much higher degree than the normal. A violet strongly luminous is sufficient to induce this green, but a feeble violet, although very sensible to the normal eye, is black to the color-blind in question. It is plain that the violet-blind, whose primitive colors are red and green, do not confuse these colors. This kind of blindness, from the experiments made so far, must be very rare."

The only serious rival to the Young-Helmholtz theory, is that of Hering.

Hering's theory. Hering's theory of colors is based upon an analysis of color sensations. He assumes a "visual substance" which is a mixture of three others; one, which determines the sensation of black and white, another, which determines that of red and green, and a third, which determines that of yellow and blue. The red light acts on the red-green substance, causing a katabolic change (dissimilation) which produces a sensation of red. The green light on the contrary, would cause an anabolic change in the substance by its action (assimilation) which would produce the sensation of green. The same takes place in the case of the yellow and blue rays, in relation to the yellow-blue substance. The intermediary rays act on the two substances alike. But all the rays act on the white-black substance, which Hering expresses by saying that these rays, have besides their color value (Valenz), a white value (Valenz) also. It is not only the white light, but also the colored rays, which dissimilate this substance. If the two other substances did not exist, all the rays would produce a white sensation, but of different brightness. This is what takes place in individual achromatics. If only one of the two substances is wanting we have the dichromatic system. Hering supposes therefore, that there are four principal colors: red and green, yellow and blue, and he thinks that we have a direct impression of the fact that these four colors are unitary, and that the others, perceived by an action on the two substances together, are color-blends or non-unitary chromatic sensations.

Hering's theory is a vast improvement over that of Helmholtz, in that it takes account of the fact that there are five fundamental (unitary) light-sensations, red, yellow, green, blue and white—that is to say that *yellow* and *white* are simple, unique, experiences, and not combinations respectively of red and green, or of red and green and blue, *sensations.* This is an addition to correct thinking in the domain of color the importance of which cannot be over-estimated. No color theory hereafter can ignore this fundamental psychological fact—a fact which was well known, indeed, to Leonardo da Vinci, to Goethe, and to all writers who have discussed color before the Helmholtz period. The Helmholtz theory obscured this fact and took account only of the phenomena of "matching by mixtures;" this theory has been well said to be pre-psychological as well as pre-evolutionary.

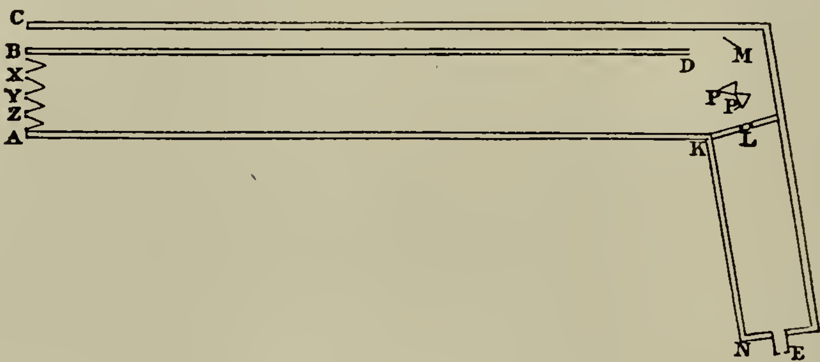
Preyer's theory. According to Preyer's theory, the sense of color has developed from a sense of temperature, and is to be conceived as an extremely refined sense of temperature restricted to a most sensitive expansion of nerves—the retina. Color-perceptions vary only in intensity and quality. Intensity or brightness depends upon

the degree of the excitation; the quality, upon the frequency of the exciting vibrations. All rays of light with a wave-length considerably greater than 0.0000546 of an inch furnish warm colors; all those with a wave-length considerably smaller, cold colors. In accordance therewith, the spectrum is divided into a warm and cold half, which are opposed to each other. Every optic-nerve fibre ends in the retina in two cones, one of which is excited only by warm colored, the other only by cold colored light rays; these excitations are received by the ganglion-cell of the retina, which transmits to the brain either the former or the latter, but never both together. In the normal eye the cones are present in even proportion, and they are so arranged that the warm cones, sensitive to red and yellow, are at equal distances from each other and from the cold cones, sensitive to green and blue; so that even in the smallest retinal image all color-excitations may be present. All color-perceptions are only affected by simultaneous excitation of the two pairs of cones. If the excitation with any one color increase, it becomes brighter, whitish, and eventually white; if it decrease, the color becomes dark and finally black. If the red and green cones, complementary couples, are excited simultaneously, and in equal intensity, the nerve undulations produced by the two kinds of ether vibrations are propagated separately as far as the peripheral ganglionic cells; but thereafter, as the one nerve-fibre cannot at one time be excited in a twofold manner, neither of them produces any effect in the central organ. Although no color is perceived, the vibrations of the nerve-substance, if strong enough, cause an increase in the excitation proper of the retina, i. e., a colorless or white sensation.

Many other theories of color have been advanced from time to time; the *correlation theory,* described by Oliver; the theories of Ebbinghaus, Parinaud, V. Kries, Koenig, etc., and for a more complete discussion of the recent theories, which take account of our actual knowledge of physico-chemical processes, see **Color-vision, Theories of,** in this *Encyclopedia.*

An independent investigator of this subject was Clerk Maxwell, who experimented with a "color-box" of his own design, by which he mixed the simple colors of the spectrum, and the results he got are really the first which are founded on measurement. He measured something, but hardly arrived at the color sensation. Describing the method, in the *Philosophical Transactions of the Royal Society* for 1860, he says: "The experimental method which I have used, consists in forming a combination of three colors belonging to different portions of the spectrum, the quantity of each being so adjusted that the mixture shall be white, and equal in intensity to a given white. The

instrument for making the observations consists of two tubes, or long boxes of deal, of rectangular section joined together at an angle of about 100°. (See figure.) The part A K is about five feet long, seven inches broad, and four deep; K N is about two feet long, five inches broad, and four deep; B D is a partition parallel to the side of the long box. The whole of the inside of the instrument is painted black, and the only openings are at the end A C and at E. At the angle there is a lid, which is opened when the optical parts have to be adjusted or cleaned. At E is a fine vertical slit, L is a lens; at P there are two equilateral prisms. The slit E, the lens L, and the prisms P are so adjusted, that when light is admitted at E, a pure spectrum is formed at A B, the extremity of the long box. A mirror at M is



Maxwell's Color-Box.

also adjusted so as to reflect the light from E, along the narrow compartment of the box to B C. At A B is a rectangular frame of brass, having a rectangular aperture of six inches by one. On this frame are placed six brass sliders, X Y Z. Each of these carries a knife-edge of brass in the plane of the surface of the frame. These six movable knife-edges form three slits, X Y Z, which may be so adjusted as to coincide with any three portions of the pure spectrum formed by light from E. The intervals behind the sliders are closed by hinged shutters, which allow the sliders to move without letting light pass between them. The inner edge of the brass frame is graduated to twentieths of an inch, so that the position of any slit can be read off. The breadth of the slit is ascertained by means of a wedge-shaped piece of metal, six inches long, and tapering to a point from a width of half an inch. This is gently inserted into each slit, and the breadth is determined by the distance to which it enters, the divisions on the wedge corresponding to the 200th of an inch difference in breadth, so that the unit of breadth is .005 inch. Now suppose light to enter at E, to pass through the lens, and to be refracted by the two prisms at P, a pure spectrum, showing Fraunhofer's lines, is

formed at A B, but only that part is allowed to pass which falls on the three slits X Y Z. The rest is stopped by the shutters. Suppose that the portion falling on X belongs to the red end of the spectrum; then, of the white light entering at E, only the red will come through the slit X. If we were to admit red light at X, it would be refracted to E, by the principle in optics that the course of the ray may be reversed. If, instead of red light, we were to admit white light at X, still only red light would come to E; for all other light would be either more or less refracted, and would not reach the slit at E. Applying the eye at the slit E, we should see the prism P uniformly illuminated with red light, of the kind corresponding to the part of the spectrum which falls on the slit X, when white light is admitted at E.

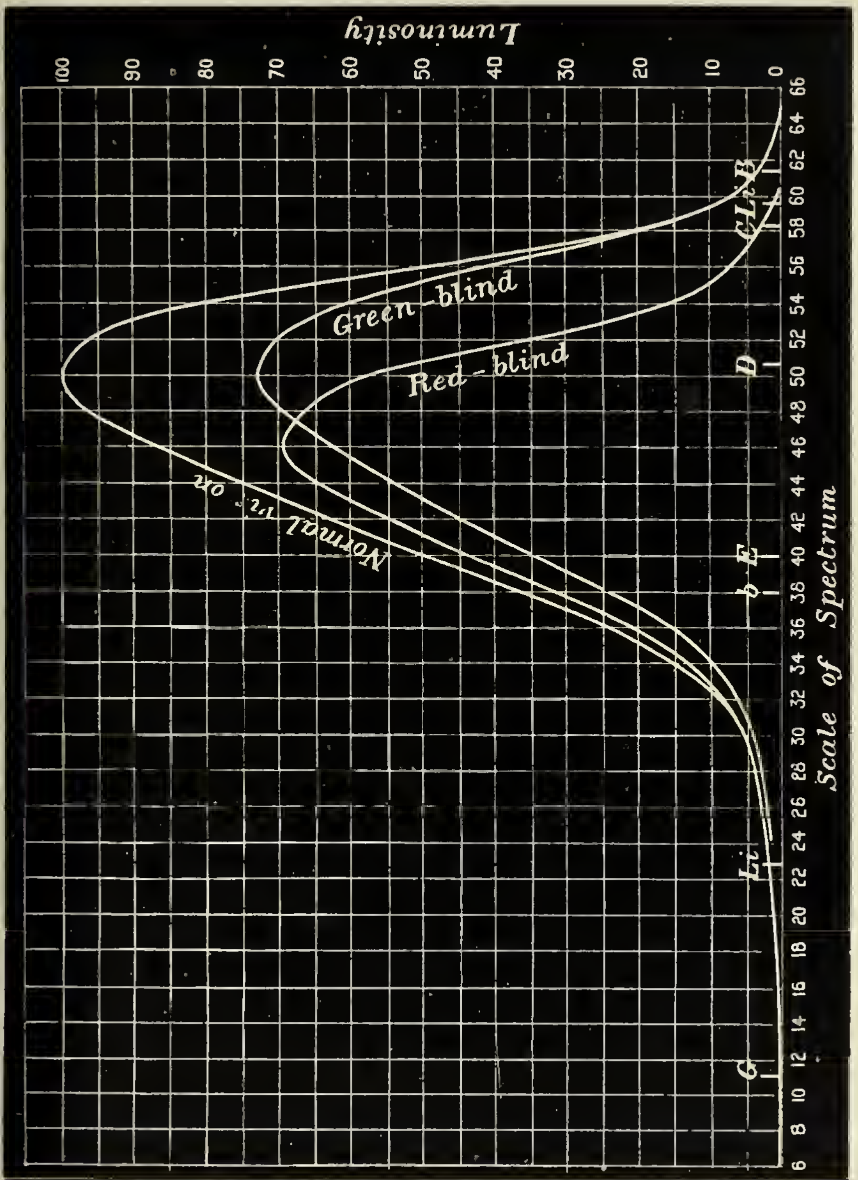
Let the slit Y correspond to another portion of the spectrum, say the green; then if white light is admitted at Y, the prism as seen by an eye at E, will be uniformly illuminated with green light; and if white light be admitted at X and Y simultaneously, the color seen at E will be a compound of red and green, the proportions depending on the breadth of the slits and the intensity of the light which enters them. The third slit, Z, enables us to combine any three kinds of light in any given proportions, so that an eye at E shall see the face of the prism at P, uniformly illuminated with the color resulting from the combination of the three. The position of these three rays in the spectrum is found by admitting the light at E, and comparing the position of the slits with the position of the principal fixed lines; and the breadth of the slits is determined by means of the wedges. At the same time, white light is admitted through B C to the mirror of black glass at M, whence it is reflected to E, past the edge of the prism at P, so that the eye at E sees through the lens a field consisting of two portions, separated by the edge of the prism; that on the left hand being compounded of three colors of the spectrum refracted by the prism, while that on the right hand is white light reflected from the mirror. By adjusting the slits properly, these two portions of the field may be made equal, both in color and brightness, so that the edge of the prism becomes almost invisible.

In making experiments, the instrument was placed on a table in a room moderately lighted, with the end A B turned towards a large board covered with white paper, and placed in the open air, so as to be uniformly illuminated by the sun. In this way the three slits and the mirror M were all illuminated with white light of the same intensity, and all were affected in the same ratio by any change of illumination: so that if the two halves of the field were rendered equal

when the sun was under a cloud, they were found nearly correct when the sun appeared again. No experiments, however, were considered good unless the sun remained uniformly bright during the whole series of experiments. After each set of experiments light was admitted at E, and the position of the fixed lines D and F of the spectrum was read off on the scale at A B. It was found that after the instrument had been in use some time, these positions were invariable, showing that the eye-hole, the prisms, and the scale might be considered as rigidly connected.''

Another method of experimenting with color vision, is by the use of the so-called luminosity curves. If the whole spectrum is thrown upon a screen, and a person with normal vision is asked to point out the brightest part, he will indicate the yellow, while a red-blind person will say the green, and so on. This means that the various types of color-blind must see their spectrum colors with luminosity differing from that of the normal eye. The difference can be measured by causing both to express their sense of the brightness of the different parts of the spectrum in terms of white light, or of one another. Brightness and luminosity are here used synonymously. Let a patch of red and one of green monochromatic light be thrown on two small screens. The green appears to be much brighter than the red. Rotating sectors, the apertures of which can be opened or closed at pleasure during rotation, are now placed in the path of the green ray. The apertures are made fairly small, and the green is made to appear evidently dimmer than the red. When they are well open the green is once more brighter. Evidently at some time during the closing of the apertures there is one position in which the red and the green must be of the same brightness, since the green passes through the stage of being too light to that of being too dark. By gradually diminishing the range of the ''too open'' to ''too dark'' apertures we arrive at the aperture where the two colors appear equally bright. The operation of equalizing luminosities must be carried out quickly and without concentrated thought, for if an observer stops to think, a fancied equality of brightness may exist, which other properly carried out observations will show to be inexact. Now, instead of using two colors, we can throw on a white surface, a white patch from the reflected beam, and a patch of the color coming through the slit alongside and touching it. The white is evidently the brighter, and so the sectors are placed in this beam. The luminosity of, say, a red ray is first measured, and the white is found to require a certain sector aperture to secure a balance in brightness. We then place another spectrum color in the place of the first, and measure off in

degrees the brightness of this color in terms of white light, and we proceed similarly for the others. To prove that the measures for luminosity of the different colors are correct, we place three slits in the spectrum, and by altering the aperture of the slits, make a mix-



Curves of Luminosity.

ture of the three rays so as to form white. The intensity of this white we can match with the white of the reflected beam. We can then measure the brightness (luminosity) of the three colors separately, and if our measures are correct there is prima facie reason to suppose that they will together make up the brightness of the white. As

in the color patch apparatus all colors and principal dark lines of the solar spectrum are known by reference to a scale, in making a graphic representation of the results, we first of all plot on paper a scale of equal parts, and at the scale number where a reading is made, the aperture of the sectors in degrees is set up. Thus, suppose with red light the scale number which marked the position of the slit was 59, and the aperture 10°, we should set up at that scale number on the paper a height of 10 on any empiric scale. If in the green at scale No. 38 the sectors had to be closed to 7°, we should set up 7 at that number on the scale. When observations have been made at numerous places in the spectrum, the tops of these ordinates, as they are called, should be joined, and we then get the observed curve of luminosity for the whole spectrum. For convenience, we make the highest point 100, and reduce the other ordinates in proportion. For some purposes it may be of advantage to give the luminosity curve in terms of a scale of wave-lengths. Now, if we test the vision of the various types of color-blind by this plan, we should expect to get luminosities at different parts of the spectrum which would give very different forms to these curves. We cannot hope, for instance, that a red-blind who sees no red in the extreme end of the spectrum, would show any luminosity in that region, nor that the green-blind should show as much in the green part of the spectrum as those who possess normal color vision, since one of the sensations is absent. With monochromatic vision there should be a still further departure from the normal curve. That these differences do exist is fully shown in the figure.

Besides cases of complete blindness due to the absence of one or two sensations on the Young theory, there are other cases in which one or even two sensations are only more or less deadened. It has often been said that with the theory provisionally adopted, such cases are difficult to class as red or green deficient. The luminosity curves of such observers, combined with other indications, give a ready means of classifying them. The main difficulty is to state what is normal color vision. In numerous experiments which Lord Rayleigh has made in matching orange by means of a mixture of red and green, he has come across several who have apparently normal vision, as they see colors correctly in every part of the spectrum, and yet some require much less red mixed with the green to make a match with the orange than do others. What is yellow to them is decidedly green to the majority. This has been classed as another kind of normal vision; but the luminosity curves show that it may be equally well due to a deficiency in the green sensation, and which would re-

quire more green to make the necessary match. The limits of the visible spectrum to these persons are the same as to one of normal vision.

Looking at color-blindness in its historical aspect, we find that in the year 1684 Dr. Tuberville was consulted by a woman thirty-two years of age in regard to her eyes. She had excellent vision in other respects, but could not distinguish one color from another. This is the first case of color-blindness recorded in literature, though it must have existed for centuries before this. Subsequently other cases were observed and reported from time to time, but it was not until 1774 that the condition was scientifically investigated. In 1794 Dalton, the celebrated English chemist who was himself red-blind, published an account of his own case, and his interest in the subject led to the discovery of twenty persons possessed of the same peculiarity of vision as himself. He did not suspect his defect for some time, attributing his frequent mistakes to a faulty color nomenclature. He saw no difference between the color of a laurel-leaf to that of a stick of red sealing-wax; and the various tints of the rainbow, were narrowed down to yellow and blue. On one occasion Dalton is said to have appeared at the Quaker meeting of which he was a member in the usual drab coat and small clothes of the sect, with a pair of flaming red colored stockings. Many years later, when he was invested with the scarlet gown of the University, he compared its color to that of the trees. The thing that first convinced him of his defect was his observations of a pink geranium by candle-light. "The flower," he says, "was pink; but it appeared to me almost an exact sky-blue by day. In candle-light, however, it was astonishingly changed, not having any blue in it; but being what I call a red color which forms a striking contrast to blue." He goes on to remark that all his friends except his *brother* (mark this relationship), said: there was not any striking difference in the two colors by the two lights. He then investigated his case by the solar spectrum, and became convinced that instead of having the normal sensations, he only had two, or at most three. These were yellow, blue, and perhaps purple. In yellow he included the red, orange, yellow, and green of others, and his blue and purple coincided with theirs. He says, that "part of the image which others call red, appears to me little more than a shade or defect of light; after that, the orange, yellow and green seem one color, which descends pretty uniformly from an intense and a rare yellow, making what I should call different shades of yellow. The difference between the green part and the blue part is very striking to my eye, they seem to be strongly contrasted. That

between the blue and the purple much less so. The purple appears to be blue much darkened and condensed.''

Dalton said a florid complexion looked blackish-blue on a white ground. Blood looked like bottle-green, grass appeared very little different from red. Colors appeared to him much the same by moonlight, as they did by candle-light. By the electric-light and lightning, they appeared as in day-light. Because of his interest in the subject, color-blindness received the name Daltonism, though this has been objected to, on the commendable ground that his name should be honored on account of some of his notable achievements, rather than because of this unfortunate defect which he possessed. Recent investigations tell us that such color-blindness is by no means rare, nor could it have been then. Statistics, derived from carefully carried out examinations made in various parts of the world by an approved method of testing, show that about four out of every hundred males, suffer from some deficiency of color perception, but that so far as the more limited statistics regarding them are to be depended upon, only about four of every thousand women suffer in the same manner.

Prof. Whewell proposed the term Idiopts signifying peculiarity of vision, but, as Sir David Brewster remarked, ''the important consonant *p* would be apt to be omitted in ordinary pronunciation, and so the last state of the Idiopt would be worse than the first.'' The term color-blindness, in general use at the present day, was first suggested by Brewster. Up to the year 1837 color-blindness was looked upon as a very rare affection; no practical method of investigation had been devised, and the cases seen were accidentally discovered. In this year Seebeck examined the students of a school in Berlin, and began the systematic collection and comparison of cases. He rejected the idea of attempting to discover color-blind individuals by asking them to give the names of colored objects. The patient was directed to arrange, in the order of their resemblances to each other, about three hundred pieces of colored paper, which were in confusion. He also used pieces of colored glass and wool as test objects, but objected to silk on account of its brilliancy. By comparing the manner of arranging the colors, Seebeck succeeded in pointing out two distinct classes of color-blindness. He also recognized the existence of many cases of partial defect, and of others where there was but a slight departure from the normal.

In 1850 Helmholtz brought to public attention the almost forgotten theory of the three primitive colors or fundamental perceptions devised by Thomas Young at the beginning of the nineteenth century. Slightly modified, it seemed to offer a satisfactory explanation of

color-blindness, and under the name of the Young-Helmholtz theory excited wide interest. Fifteen years later, Hering announced the doctrine of four cardinal colors, which found much favor, and continues to rival the Young-Helmholtz theory in the number of its adherents. In 1854 George Wilson, professor of technology at the University of Edinburgh, undertook the investigation of color-blindness from a practical standpoint. He was led to this study by the mistakes made by the students of his laboratory in judging the colors of chemical precipitates. For a long time he scarcely dared suspect any of his pupils of having so rare an infirmity; but after reading Dalton's memoir, he proceeded to make an examination and found, much to his surprise, that his suspicions were correct. Proceeding to make a systematic search for color-blind individuals, he examined students, soldiers, policemen, etc., and out of 1,154 persons examined, he discovered that 5.6 per cent, or about one out of every seventeen persons were color-blind. Wilson's work was of great importance, as his constant aim was to direct attention to color-blindness in its connection with practical life. He shows that the color-blind are totally unfit to become painters, dyers, weavers, tailors, chemists, botanists, geologists, physicians, seamen, or railroad employés. He especially mentions the dangers which threaten travel by rail and sea because of the peculiar liability of the color-blind to mistake the red (danger) and green (safety) signals in common use. At about this same time Dr. Favre, of Lyons, France, was engaged in investigating the color-sense among the employés of the Paris-Lyon-Mediterranean Company. He found 98 color-blind out of 1,050 men examined (9.33 per cent). His methods and results are not reliable, as he undoubtedly confounded color-blindness with the much more common condition of color-ignorance. Notwithstanding the repeated warnings of Wilson as to the danger of employing color-blind men on railroads, little was done in a practical way until Professor Holmgren, of the University of Upsala, became interested in the subject. In 1875 a serious railway accident occurred in Sweden, which intensely excited public attention. At the investigation which followed, it was found that color-blindness was one of the principal causes of the disaster. From this fact Professor Holmgren became convinced that the color-sense of the employés should be under official control. To secure this reform he realized that it was of the highest importance to have a practical method of examination, which should be rapid and certain without incurring heavy expense or requiring extensive preparations. After much study Professor Holmgren perfected his method, which is based on the Young-Helmholtz theory and has the merit of being at

once simple, rapid, and accurate. The method was tested on 2,220 soldiers, when it was found that one minute was the average time required to examine one man. Having secured a practical method, his next endeavor was to personally interest the railroad managers in the matter. As Holmgren says: "It naturally became an object of attention to railway officials, although received by a greater portion of them with a certain mistrust, seeing in it the result of a scientist's imagination or an overwrought solicitude, rather than a matter of practical application for the benefit of the railways. 'If color-blindness really exists,' they said, 'it cannot, at any rate, be among the employés, or it would undoubtedly have been remarked; especially must this be the case among the engineers and conductors, as they rise from inferior grades, and consequently, have amply proved their ability to distinguish signals.'" Through the kindness of the superintendent-in-chief of the Upsala-Gefle line, Holmgren was enabled to examine the entire personnel of the road, and discovered thirteen color-blind men out of 266 individuals examined (4.8 per cent). This inspection proved conclusively that color-blindness did exist among railroad employés without there having been the slightest suspicion of it. Through the efforts of Holmgren a law was enacted in Sweden under which no one can be taken into the employ of a railroad company until his color-vision has been tested and has been found sufficient for the duties he will be called upon to perform.

When occurring in a healthy subject, color-blindness is always congenital and is usually hereditary. It is curious to trace back in some instances the color-blindness, when it is to be found, in a family: as has been pointed out by Abney. It often happens that color-blindness —as the gout is said to do—skips a generation. This is usually traced to the fact that the generation skipped is through the mother. Thus, the maternal grandfather may be color-blind, as may be the grandsons, but the mother will very frequently have perfectly normal vision for color. On the other hand, the paternal grandfather may have defective color perception, and this may be inherited both by the grandsons and the father. The remark made by Dalton regarding his brother's eyesight points to the fact that his own color-blindness was probably hereditary. Deaf-mutes, Jews, and Quakers, seem to be more liable to color-blindness than other people, statistics giving them 13.7, 4.9, and 5.9 as the percentages. This deficiency in color perception is totally distinct from that which may arise from disease. This last form has such marked characteristics of its own, that it can at once be distinguished from the congenital form. Of the four per cent. of males who suffer from congenital color deficiency of vision, a

large number are not totally lacking in any one or more color sensations. Those in whom one sensation, on the Young theory, is entirely missing are called "completely red-, green-, or violet-blind," while those in whom the sensation is but partially deadened are called "partially red-, green-, or violet-blind." When two sensations are entirely absent, and such cases are very rare indeed, they are generally said to have monochromatic vision: that is, every color to them is the same, as is also white, the only distinction between any of them, being the superior brightness of some over others. The best illustration of this form of color vision is perhaps to say that the retinæ of such people have the same characteristics in regard to sensitiveness as has a photographic plate, the resulting prints in black and white representing what it sees in nature.

Examining a red-blind person with the spectrum, we find that he sees no light at all at the extreme limit of our red, and only when he comes to the part where the red lithium line marks a certain red does a glimmer commence; he then sees what he may call a dark-green, or dark-yellow. When questioned about what to us are greens he also calls them green or yellow, some being bright, others saturated hues, and others again paler. When he gets to the bluish-green he calls it gray, and will say it is indistinguishable from, and in fact will match with, a white degraded in tone. From this point he will say he sees pale blue, blue, and in the violet, dark blue. Too much importance must not be attached to the nomenclature adopted by the color-blind. They have to take the names of the colors from the normal-eyed. Yellow objects are generally brighter than red, and having annexed the idea that what to them is bright red is called yellow, they give it that distinguishing name. His limit of vision at the violet end will be the same as the majority of mankind, but it will be considerably shortened at the red end. The point in the spectrum which he calls gray is an important point, and corresponds to the place where the violet and green curves cross.

If a similar examination be made of the green-blind, the red end of the spectrum will be called red or yellow, but the spectrum itself will be visible between the same limits as it is to the person who has the normal sense of vision. A gray stripe will be seen in the spectrum, but in this case it will be a trifle nearer the red end of the spectrum than the point which the red-blind calls gray; from this point to the extreme violet, the green-blind will name the spectrum colors similarly to the red-blind. The part of the spectrum where gray exists to the green-blind, is even more important than that part at which it exists to the red-blind, for it marks the place where the red

and violet curves cross, and is in the majority of cases the place in the spectrum where to the normal eye the green sensation is unmixed with any sensation except that of white. This green evidently is the color which is most usefully employed in making color mixtures in order to obtain the three sensation curves of the Young theory, since white can be added to the color matched.

It is a very remarkable fact how many people who are defective in color vision pass through a good part of their lives without being definitely aware of it. It is very doubtful whether, in the majority of cases, they themselves discover it. They may quite possibly attribute the descriptions of colors which they hear, and which appear to them absolutely false or meaningless, as due to mental or moral defects in their friends. Abney mentions the case of one of his patients, a gentleman of seventy-four, who had no conception that he had anything but normal color-vision: his daughters, however, had a suspicion that something was not quite right in it, and after a good deal of persuasion, brought him for examination. His first mistake was to state that he was sitting on a black velvet chair, whereas the seat was a deep crimson plush. He laughed at his daughter's description of his mistake, and declared he was only color-ignorant, and that she was the one who was color-blind. The examination showed that color-ignorant he was, but that the ignorance was due to complete red-blindness. For the seventy-four years he had lived he was unaware of his deficiency, suspecting it in others, and it was only an accidental circumstance which made him acquainted with the true state of his color perception. Another elderly gentleman, in a high position in life, was also accidentally tested, and he proved to be completely green-blind. He, too, was quite unaware of his defect, and protested that, yachtsman as he was, he would never mistake a ship's lights; but a very brief test showed his friends who were with him that his declaration had to be received with a certain amount of reservation.

For the practical recognition of color-blindness, the device that is most commonly used for ordinary clinical purposes today, is best known by the wools of Holmgren that were borrowed from the papers of Seebeck and the worsteds of Wilson. Modified in all manner of ways by assortments of fixed colors that have been arbitrarily and even foolishly arranged upon cards, sticks, spools, cones, discs, and other articles, it has suffered the most varied of vicissitudes, only to come back to the original plan of loose-wool selection that was strenuously sought for by both Wilson and Holmgren. Nagel's "Anomaloscope," an instrument in which spectral colors only are used; Adler's

crayons; Maxwell's and Woinow's revolving discs; Hierlinger's and Magnus's tables; Lip's color triangles; the optotypi of Snellen; the color-tables of von Reuss, Daae, and Roberts; the yarn-covered spools of Schenke; Kolbe's truncated cone, the pseudo-isochromatic wools of Donders, the embroidery patterns of Cohn, and the stick of Thomson, constitute the majority of the devices that have been successively championed and upheld by their individual contrivers.

The more or less fixity of the tests, thus limiting the number of colors from which a choice might be taken; also the liability of the methods to become known and understood, and thus rendered practically worthless when pursued among a great number of similarly placed individuals, are some of the main reasons why these latter plans cannot be satisfactorily employed.

The method of testing by direct comparison of the spectral colors, unfortunately cannot be brought into every-day employment as an ordinary test for the quick detection of lowered color sense, although it can be made to serve a useful purpose in cases requiring more than ordinary observation, as among persons under judicial action. The apparatus is expensive: its mechanism is complicated and liable to become disarranged; both the examiner and the candidate must possess the necessary intelligence to handle the instrument; and the dealing with spectral colors which are not the ones that the candidate is brought in daily touch with—these are some of the reasons why this plan must be relegated to the determination of a few selected cases.

The double spectroscope of Hirschberg, the polariscope of Rose, and the chromatophotoptometer of Chibret, are among the principal and most ingenious contrivances employed in this method.

Attempts have also been made to detect faulty color-perception by the study of subjective after-color (complementary color). This method however is practically useless. Much time and energy have been expended upon it. Contrivances of all kinds to show simultaneous and successive contrast colors have been devised. Prominent among them are the Heidelberg and Pflüger color-books, Scina's mirror-contrast apparatus, Stilling's so-called chromatoskiameter, and Cohn's chromaskiopticon. Unfortunately, in this series of experiments, vague subjective colors are dealt with; uncertain color intensities, and, in fact, absolute changes of color vibration are used; and the adjustments of the instrumental technique are frequently uncertain and misleading. In addition the candidate is required to compare the subjective color with some known series of colors such as wools and papers, which might as well have been done primarily by the ordinary method of loose-wool selection. A contrivance has been

devised by Zeeman and Weve, of Amsterdam, for determining the color-sense which combines the following advantages: Special colors and their admixture in all wave-lengths, saturation, and intensity can be presented to the observer; they can be combined quantitatively with light of known intensity and wave length; the examinee is always under the control of the examiner; the apparatus is practical and inexpensive.

For the study of the color sense in railway and marine services, resource must be had to another plan, which consists in placing the candidate in the actual position in whieh he is afterward expected to discern properly the colors employed for signalling purposes. The lantern test, which is used in this method, to be of any practical value must be carried out in such a way as to resemble the actual conditions whieh are supposed to exist while the candidate's eolor sense is protecting life and property. Wilson in 1855 determined that not only could color be recognized correctly at short distances and not distinguished at longer ones where such eolors were plainly discernible to the normal-sighted, but he also found that the sensitiveness to colors, while being gazed at, became more quickly lost as they were removed from the eye of the "color-blind" than when they were removed from the unimpaired visual organ. This, which he aptly termed "chromie-myopia," or "short-sightedness to color," expresses in a word or two why candidates for positions necessitating color recognition at comparatively long distances, or "safety distances," eannot be considered as adequately determined when they have been tested by the ordinary methods of loose-wool selection or other near-at-hand tests. The findings at one or even two metres' distance are in cases of this character worse than useless: they are dangerous. Loeomotives, for example, moving at a high rate of speed, would be propelled into destruction long before any engineer with "chromic-myopia" could check their speed.

In view of the appalling number of industrial accidents happening every year, and even every day, representing an annual loss of thousands of lives and millions of dollars, it is a question of the most vital importance, whether the color scheme of danger signals which has so long been in vogue and so universally used, is not an antiquated system, devoid of any scientific *raison d'être* as some investigators contend, and which should be supplanted by a system, which from more recent investigations into the color-sense, would be vastly superior to the present system. There are according to those who hold this view certain fundamental objeetions to the present method. These

Disc to Illustrate the Danger-signal, as Proposed by Francis D. Patterson.

are briefly summarized by Francis D. Patterson, in *Drugs, Oils and Paints* (see figure) as follows:

First. Of the large number of individuals who are color-blind—about four per cent of males—the great majority of this number are either red or green-blind, or a combination of the two. To such persons red conveys no warning of danger to their eyes: it is any shade from gray to black or green, if perceived at all. These persons are surely entitled to the protection which is denied them if the color red is used.

Second. Red is a fugitive color: it is evanescent and it is difficult to distinguish in a poor light.

Third. Red fades on exposure to sunlight, and unless repainted at frequent intervals turns white. Railroad employés, and those who follow the water, at least if they have any responsible positions as the pilot or quartermaster, are obliged to be perfect in their color vision and are subjected to frequent and careful examination to see that they are so. The elimination of all afflicted with any form of color-blindness from industrial work, however, would involve a hardship both upon the employé and the employer, which would be wholly unnecessary and unwarranted.

Experiments have shown that the best colors for a universal danger signal are yellow and blue. The reasons for this are:

First. Yellow and blue are the only colors which give rise to a normal color sensation as soon as they become visible as colored. For this reason they can be seen at a greater distance in daylight and they are more easily distinguishable in a poor light than any other color or combination of colors.

Second. All other colors appear either yellow or blue until they pass inside of the yellow blue area of the eyes, when they are recognized in their natural colors.

Third. Yellow and blue are the most luminous colors of the spectrum.

Fourth. Those rare cases where the ability to see yellow and blue are impaired will call them red or green and so receive a protection which the color red would not give them.

Fifth. Yellow and blue are more permanent colors and quite fast to sun light.

On the other hand, we know that a blue glass, as commonly met with, transmits many red rays besides the blue ones, allowing four per cent of the naked light behind it to pass through it, while by a glass of fairly pure blue the luminosity would be reduced to about two per cent. This luminosity in foggy weather would be reduced to nothing,

a great danger in our times of high speed, where it is necessary to recognize the color of the light a few thousand feet away. A yellow signal would be luminous enough, but under certain circumstances would appear too much like white. Green transmits from ten to twenty per cent. of the luminosity of the light behind it, and red about ten per cent. Hence, for practical purposes red and green are the safest colors that can be used for signals, and no color-blind person should be allowed to be in any position where quick and accurate distinction between red, green, and white is an absolute necessity. An organization called "The National Council for Industrial Safety" is attempting, with the cooperation of men who are experts in this line of investigation, to determine the color or set of colors which will most accurately fulfill all requirements, and then to recommend its adoption as a universal danger signal.

Coming now to the more practical part of the subject, it is evident that a good working hypothesis is absolutely necessary before effectual tests for color-vision can be carried out, and that the reasons for its adoption should be given in full. The question of color-blindness is one of very great importance, and the investigation of a patient's capacity to discriminate between colors is no longer a matter of academic interest alone: it is no longer associated in practice only with the examination of railway men and seamen: it is becoming an additional aid in the diagnosis of localization.

In certain occupations it is essential that colors should be accurately and quickly recognized, and that no guess-work should be allowed. More than forty different methods have been devised for the detection of color-blindness. A description of the most important ones will be given here. Whatever method is used the following facts, as recently pointed out by Edridge-Green, are of practical importance.

1. Most color-blind make mistakes with certain colors, but are correct with regard to others.

2. The color-blind name colors in accordance with their color-perception, and thus show definitely to which class they belong.

3. Colors may be changed to the color-blind, whilst leaving them unaltered to the normal-sighted.

4. The phenomena of simultaneous and successive contrast are much more marked for the color-blind than for the normal sighted.

5. Many color-blind match correctly, but name the principal colors wrongly.

6. Many color-blind recognize colors easily when they are close to them, or the surface is large, but fail to distinguish between them when they are at a distance or the image on the retina is small.

7. The color-blind are more dependent upon luminosity than the normal sighted, and are liable to mistake a change in luminosity for a change of color.

8. The color-blind find special difficulty with faint and dim colors.

9. The color-blind who have shortening of the red end of the spectrum cannot see reds reflecting or transmitting only rays corresponding to the shortened portion.

10. The color-blind find more difficulty in comparing colors when different materials are used, than when the colored objects are all of the same nature.

11. Most color-blind find more difficulty with transmitted than with reflected light.

12. The color-blind have a defective memory for colors.

13. Colors may be changed to the normal-sighted whilst leaving them unchanged to the color-blind.

14. The color-blind may have a sense of luminosity similar to that of the normal-sighted.

15. The dichromic distinguish between the colors of the normal-sighted, which are included in one of theirs by their relative luminosity and the difference of saturation which is apparent to them.

16. Color-blindness is frequently associated with very high intelligence and exceptional ability.

But one eye at a time should be examined, because even if only one eye is defective, the sound eye might become incapacitated from the presence of dust, or a foreign body in the cornea, at the very moment when the recognition of the color is necessary, and by closing the normal eye at this time, serious results might follow.

Holmgren's wool test, or one of the several modifications of it, is probably the most widely used of any of the methods yet devised, and because of its importance will be described in detail. This test however has been severely criticized on the ground that it may reject (approximately) normal, and let pass the distinctly and dangerously abnormal. While in the Holmgren test it is of importance that the person under examination should not be permitted to name the colors. Edridge-Green insists strongly and with justice that naming of the colors should form an integral and vital part of the examination, not merely silently arranging them. He does so on the perfectly just contention that the locomotive engineer, for example, says to himself, "That is a green light," or "That is a red light." He has to name it to himself before he can decide what his duty is. For this purpose Edridge-Green has devised a lantern by means of which a colored light can be exhibited alone or modified in imitation of varying

atmospheric and other conditions such as must present themselves to the engineer or mariner. His correctness or his errors are thus plain for all to see; and the very natural resentment of the worker on rejection after investigation by what he considers to be an unfair and unsuitable test is done away with.

As a preliminary, before proceeding with the examination by the Holmgren method, it must be remembered that a color has three constants, which together determine its unambiguity: 1. *hue;* 2. *purity, tint,* or *saturation;* and 3. *brightness* or *shade;* and matching it exactly with another color would for a normal eye require this latter to have these three constants also the same. The color-blind person mistakes the *hues,* but still looks for the same *purity* and *brightness* as in the test-skein. This would require, however, an immense number of wools, in order that the confounded hues should be present in the proper admixture with white and the corresponding brightness to be of perfect quality for the color-blind eye. Equality, therefore, being impossible, similarity only can be insisted upon.

Holmgren calls attention to the point that to get *resemblance* in color, must be the main endeavor of the examinee, and that he must pick out all those wools that are somewhat lighter or darker, but of the same color. Wools are apt to deteriorate with age and by constant handling: they must therefore be renewed from time to time. Special care must be taken to have the test-skeins always of the proper character as to hue, purity, and brightness. Abney has referred the standard test-colors as approved by Holmgren to the spectrum, as follows: "The first standard is a light-green color, which can be matched with a green in the spectrum ($\lambda = 566\mu\mu$) when forty per cent of white is added. The second standard test-skein is light purple or pink, and its complementary color is a green in the spectrum of $\lambda = 510\mu\mu$. The color is diluted with forty per cent of white. The third test-skein has a color corresponding with a red of the spectrum ($\lambda = 633\mu\mu$) diluted with eighteen per cent. of white." In his own words, Holmgren thus describes his method of examination: "The Berlin wools are placed in a heap on a large table, covered by a white cloth, and in broad daylight. A skein of the test-color is taken from the pile and laid far enough away from the others not to be confounded with them during the examination. The person examined is requested to select other skeins from the pile nearly resembling it in color, and to place them by the side of the sample. At the outset it is necessary that he should thoroughly understand that he is required to search the heap for the skeins which make an impression on his chromatic sense, and quite independently of any name he may give

the color similar to that made by the test-skein. The examiner should explain that resemblance in every respect is not necessary: that there are no two specimens exactly alike: that the only question is the resemblance of the color, and that, consequently, he must endeavor to find something similar in shade, something lighter and darker of the same color, etc. If the person examined cannot succeed in understanding this by a verbal explanation, resort must be had to action. The examiner should himself pick out the skeins, thereby showing in a practical manner what is meant by a shade, and then restore the whole to the pile, except the sample skein. As it would require too much time to examine every individual in this way, it is advisable, when examining large numbers, to instruct them all at once, and to ask them to observe attentively the examination of those preceding them, so as to become more familiar themselves with the process.

This saves time, and there is no loss of security, for none with a defective chromatic sense will be able to find the correct skeins in the pile the more easily from having a moment before seen others looking for and arranging them. He will make the same characteristic mistakes; but the normal observer, on the other hand, will generally accomplish his task much better and more quickly after having seen how it has to be done. The well-known colored plate of Holmgren is for the purpose of assisting the examiner in the choice of his colors, and to help him to decide the character of the color-blindness from the mistakes made. The colors in the plates are of two characters:

1. The colors for samples (test colors): that is, those which the examiner presents to the persons examined: and,

2. The "confusion-colors;" that is, those which the color-blind will select as matches with the sample.

The first are shown on the plate as horizontal bands, and are distinguished by Roman numerals: the second are shown as vertical bands, under the test colors, and are distinguished by Arabic figures.

The colored table is not intended to be used as a test: it is simply to assist the examiner in his choice of correct test-colors, and to help him to diagnose the special form of color-blindness.

As to the similarity between the confusion-colors of the plate and the wools which the color-blind take from the heap, reliance must be placed simply on the hue, and not on their brightness or degree of color saturation. In all cases where we have to vary from this rule we must hold to the relative rather than to the absolute saturation. The confusion-colors shown in the plate are only to illustrate the mistakes which the color-blind will make, and for this purpose they serve

perfectly. Having made this examination, we can pass to the test itself.

Test I. The green test-skein is presented. This sample should be the palest shade (lightest) of very pure green, which is neither a yellow-green, nor a blue-green to the normal eye, but fairly intermediate between the two, or at least not verging upon yellowish green.

Rule. The examination must continue until the examinee has placed near the test-skein all the other skeins of the same color, or else, with these or separately, one or more skeins of the class of "confusion-colors," or until he has sufficiently proved by his manner that he can easily and unerringly distinguish the confusion of colors, or give unmistakable proof of a difficulty in accomplishing it.

Diagnosis. An examinee who places with the test skein "confusion-colors," that is to say, finds that it resembles the "test-color"—is color-blind, whilst if he evinces a manifest disposition to do so, though he does not absolutely do so, he has a feeble chromatic sense.

If it is only required to determine whether a person is color-blind or not, no further test is necessary; but if we want to know the kind and degree of his color-blindness, then we must proceed with the next test.

Test II. A purple skein is shown to the examinee. The color should be midway between the lightest and the darkest. It will only approach that given in II of the plate, as the color of the wool is much more brilliant and saturated, and bluer.

Rule. The trial must be continued until the examinee has placed all or the greater part of the skeins of the same shade near the sample, or else, simultaneously or separately, one or more skeins of the "confusion colors." If he confuses the colors he will select either the light or deep shades of blue and violet, especially the deep, or the light or deep shades of one kind of green or gray inclining to blue.

Diagnosis. 1. A person who is proven color-blind by the first test, and who in the second test selects only purple skeins, is incompletely color-blind.

2. If in the second test he selects with the purple blue and violet, or one of them, he is completely red-blind.

3. If in the second test he selects with the purple only green and gray, or one of them, he is completely green-blind.

The red-blind never selects the colors taken by the green-blind and vice versa. The green-blind will often place a violet or blue skein by the side of the green, but it will then only be the brightest of these colors. This does not affect the diagnosis. The fact that in this test, many green-blind select, besides gray and green or one of these colors,

also bright blue, has led to misunderstanding. Some have concluded from this that red and green-blindness may exist together in the same individual; others have thought that these two kinds of color-blindness are not readily distinguished by this method. The first conclusion is not correct. The two kinds of color-blindness have great similarity, but differ in innumerable slight variations. They are to be considered as two sharply defined classes. The second conclusion can arise only from not understanding and not using the method correctly. The special purpose of this method must be kept constantly in view,—viz., to find out the characteristics of the defects in color-perception of those examined. The characteristic of green-blindness is the confusion of purple with gray or green, or both. This confusion is the point to be determined; everything else may be ignored. A complete color-blind, who confuses purple with gray or green (bluish green), or with both, is *green-blind, do what else he may.* This is the rule; and the careful and observant examiner who understands the application of the test will at once distinguish it. It is, indeed, often possible, in marked cases of incomplete color-blindness, to decide to which class it belongs, by the way the examinee acts with his hands. We do not mean by this that the diagnosis is always easy. Practice and knowledge are necessary. As there is a long series of incomplete color-blindness between normal vision on the one hand and complete color-blindness on the other, there must naturally be a border-line where differences of the two kinds of color-blindness cease to be recognized.

The examination may end with this test, and the diagnosis be considered as perfectly settled. It is not even necessary, practically, to decide whether the color-blindness is red or green. But to more thoroughly convince railway employés and others, who are not specialists, of the reality of the color-blindness, the examination may be completed by one or more tests. It is not necessary to the diagnosis, and serves only as a confirmation of it.

Test III. The red skein is presented to the examinee. It is necessary to have a vivid red color, like the red flag used as a signal on railways. The color should be that of *IIb* of the plate, rather towards yellowish red.

Rule. This test, which is applied to those completely color-blind, should be continued until the person examined has placed beside the test-skein all the skeins belonging to this hue or the greater part, or else one or more "confusion-colors." The red-blind chooses, besides the red, green and shades of brown, which to the normal sense seem

darker than red. On the other hand, the green-blind selects shades of these colors which appear lighter than red.

Every case of comparatively complete color-blindness does not always make the precise mistakes we have just mentioned. These exceptions are either instances of persons who are not quite completely color-blind, or of completely color-blind persons who have been practised in the colors of signals, and who endeavor not to be discovered. They usually confound at least green and brown; but even this does not always happen. Abney suggests that the third test skein is unsatisfactory and that a skein of dark brown should take its place as the green component is then stronger, and the red blind will match not only dark green, but also light green with it. The green blind would be inclined to pick out the browns and the reds. One of the main objections to the wool test has always been the possibility of an incompletely color blind person passing all three tests. To meet this Abney suggests that in addition to the brown skein two extra skeins should be used. First a bluish purple. In this color there is but a small quantity of red, so that the incompletely red blind would fail to notice it, and would make matches of pure blue with it, and probably add blues with a small quantity of green in them. The incompletely green blind would very likely make no mistakes. Second, a slightly pale yellow. A red blind, besides the correct matches, will select skeins in which the yellow green predominates; whereas the green blind, besides the proper matches, will pick out the skeins which are decidedly on the red side of the test skein. Finally, if the examinee is asked to name some of the confusion colors, the giving of a wrong name to any of them will confirm the result.

Monochromatic Vision.—The absence of all except one color-sensation will be recognized by the confusion of every hue having the same intensity of light.

Violet-blindness will be recognized by a genuine confusion of purple, red and orange in the second test. The diagnosis should be made with discrimination. The first test often shows blue to be a "confusion-color." This may in certain cases be a sign of violet-blindness, but not always. We have not thought it advisable to recognize defects of this kind, and only the marked cases, that other tests establish as violet color-blindness, should be reckoned in the statistics."

There is no doubt that the Holmgren test if properly carried out is a very efficient one, but there are also certain objections to its use. It takes an unnecessary amount of time. It requires "careful training and is not to be learnt except by practice; for it requires not only a registration of the absolute mistakes, but also a ready observation of

the manner in which the candidate acts whilst under examination.'' Where a large number of men are to be examined, as for example, railway employes, it is a matter of great importance, to be able to secure a sufficient number of examiners who are competent to employ this test, as well as to cover the large extent of territory required to reach all the men. As far back as thirty-three years ago, the Pennsylvania Railroad Company, attempting to adopt a plan of having their employes examined for sight and color-vision, found that with about forty thousand men to be examined, and these scattered over more than five thousand miles of track, with about twelve thousand men actually depending upon colored signals for their guidance, the number of ophthalmic surgeons was too limited to make these examinations in any reasonable time. This idea was therefore given up. These considerations led Dr. William Thomson to invent a method of examining the color sense, which could be efficiently used, not only by the ophthalmologist, but by any intelligent instructed man, and a record of which could be permanently kept, for the information of the officers of the road, and as a guide for the action of any surgical expert whom the company might appoint to superintend the entire system.

This test is known as Thomson's stick. It is simply a modification of the Holmgren method of matching colored worsteds; the test-colors to be matched are green, rose, and red. The instrument and the method of its employment is described by Thompson as follows: ''The instrument consists of two flat sticks about two feet in length, and one inch in width, fastened by a hinge at one end and connected by a button at the other. Between these, and concealed from view, are forty white buttons, having the figures from one to forty clearly engraved on them, attached to the stick by small wire hooks, *which will permit of their easy removal or change of position.* To the eyes of these buttons are attached forty skeins of colored wool. In obedience to Holmgren the test skeins are three: 1, light green, A; 2, rose or purple, B; and 3, red, C. These skeins are shown to the persons examined in turns, and they are directed to select from the stick the colors which will match them.

On the stick the colors are arranged alternately to match the tests, and to be of those confusion tints which experience shows to be most commonly selected by the color-blind. The first twenty tints, set *a*, are therefore green and gray and tan-colored confusion tints, and this part suffices for detecting any color-blindness.

From 21 to 30, set *b*, the tints are alternately rose and blue, and from 31 to 40, set *c*, the tints are red, and its confusion-colors brown or sage, etc. It is arranged, however, that the real tints commence

with figure 1 and range onward by the odd figures, while the confusion-tints are designated by the even figures, so that when the entire examination is concluded—in a case of normal sight—only odd figures should appear recorded on the blank, whilst if a fault has been made by a color-blind person it will be revealed by the even numbers. In the green test, the appearance on the blank of numbers beyond 20 would be more than suspicious, with the rose anything below 21 or above 30, and with the red any number below 31. It will be seen that any superintendent or supervising expert could thus be sure of the presence or absence of color-blindness by remembering the simple theory of the arrangement and scanning the blank on which the number of tints selected had been recorded.

The first twenty tints are green and its confusion-tints, but the color-blind has the whole forty to choose from, and does frequently select reds at the end of the series, and thus proclaims his defect. Again, of these confusion-tints, five are gray, and five are shades of brown, and we may thus guess at red- or green-blindness by the first mistakes of the color-blind,—the green-blind preferring the grays, and the red-blind selecting the browns. The positions of the skeins in each set can be readily changed at pleasure on the stick.

In the rose test, between 21 and 30, the green-blind frequently select greens in the first series, and thus show their defect.

After much experience with this test, Thomson suggested some improvements which can be used as a substitution for the stick, or to be used in connection with it. The color skeins have been most carefully selected and a standard set kept, so that renewals may be made of the entire set or of those skeins that may have become faded, soiled, or lost. This test is known as the "New Wool Test." The new set consists of a large green and a large rose test-skein, and forty small skeins, each marked with a bangle having a concealed number, extending from 1 to 40, placed in a double box, so arranged to keep the two series apart, and to permit each to be exposed on a table in a confused mass. The stick is dispensed with, as giving too fixed arrangement to the skeins and not enough *confusion,* although the skeins could be readily removed from their hooks and changed in position for this purpose.

The large green skein being placed near by, the small skeins from 1 to 20 are exposed in good daylight, and the employee under examination is directed to select ten shades of the same color as the test-skein. One with normal vision will choose promptly and with ease the ten greens with odd numbers on the bangles. A color-blind person will hesitate, and his selection will contain some even numbers,

and the confusion-colors will be shades of brown, etc., containing some red, or shades of gray, and will indicate the color defect. These figures are to be recorded on a blank, and the twenty skeins are to be removed.

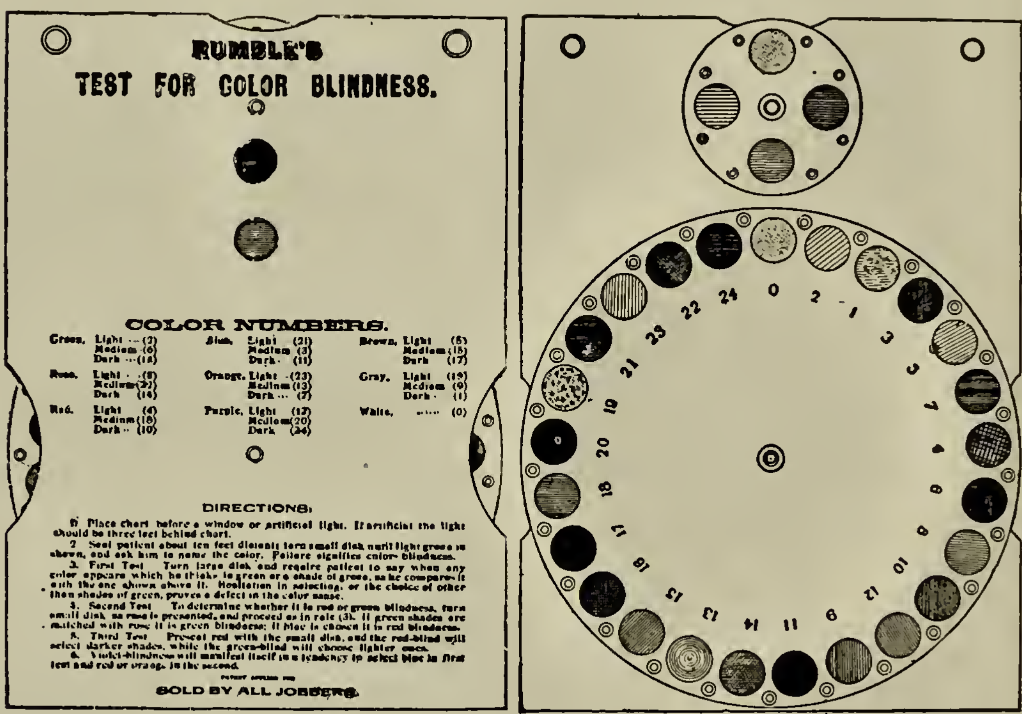
The large rose skein is then used, and the examination repeated in like manner with skeins numbered from 21 to 40, and the result recorded. The confusion-skeins, which have even numbers are blue, green, and gray. From the selections made by the man found color-defective by the green test, we are able to decide the character of his color-blindness. Those selecting blues are red-blind; those taking greens and grays are green-blind, according to the nomenclature of Holmgren. There are ten roses and ten confusion-colors in the second series.

The red test-skein of the stick with its confusion-colors is omitted entirely, and the test is made to conform more strictly with Holmgren's method, while the examiner is also provided with forty questions of decisive clearness. Greater scientific accuracy is obtained by this method, and with the careful selection of these confusion-colors, it is a safer and more simple method to be used by a non-professional examiner.

Jeaffreson devised another modification of Holmgren's test, as follows: The test-apparatus consists of a rotating celluloid disc, about a foot in diameter, upon which skeins of wools are arranged radially at the outer edge. All of the disc, except a small aperture, is covered. By means of a button attached to its center, the disc can be turned until any color is brought opposite to that standard test-color which is seen in the upper aperture. The test-skeins are the three Holmgren test-colors, and a yellow, blue, and purple. The apparatus is mounted on a frame, and hung upon a wall. In using the test, the usual course is to point out to the person under examination the pale-green wool in the upper aperture and request him to turn the button until he brings several skeins of what appear to him to be the same color on the disc opposite to the one he has to match. When the examination is completed with this color, the pink skein is proceeded with in the same manner, and this is followed by the other test-colors, if considered necessary, following it, if desired, with from one to twenty confusion-colors. The colors on the disc which are chosen can be registered by numbers for future reference, or for comparison with the results of a second examination, where in cases of dispute, it is called for.

A test recently devised by Rumble is really a counterpart of the Jeaffreson method, except that here pigment colors upon a trans-

parent disc are used instead of wools. The card is held before a window or in front of an artificial light, thus serving to a degree as a lantern test. Each test color has a number which indicates the correct name of the color in a table on the reverse side of the card (see figure) thus enabling a color-blind examiner to use the test intelligently, which cannot be done with the Holmgren method, and with



FRONT. BACK.

Rumble's Test for Color-Blindness.

The following are the leading features of this test:

—It may be used by artificial as well as day light.

—It is a true *lantern test*, and thus practical for railroad and steamboat men.

—It is adapted to the *color test blanks* now in use by railroad and marine examiners.

—It is convenient, compact, portable and inexpensive.

a number of other tests. The color-table of Dr. A. Daae, of Norway, is also based upon the principle of Holmgren. It contains ten horizontal lines of seven little squares of colored wools each. Only in two lines (No. 8 and No. 10) are all the colors alike, being different shades of green and red. All the other lines contain different colors. If any of these other lines seem to consist of shades of the same color to any person, he is color-blind, the different lines indicating the different kinds of color-blindness. This table is very convenient; but in most cases a confirmatory examination by some other test will be required.

The color-tables of Reuss, the embroidery patterns of Cohn, the colored cylinders of Badal, the yarn-covered spools of Schenke, and the rolls of pseudo-isochromatic wools of Donders, are all modifications of Holmgren's method.

Mauthner's test consists of thirty-four little glass bottles containing variously-colored powders; four of them each one powder in the fundamental colors. All the other bottles contain in superimposed layers, either two shades of the same color or two totally different colors (pseudo-isochromatic) so chosen that while they appear of different colors to the normal eye, they appear of the same color to the color-blind eye. The examination is proceeded with in the same way as with the wools.

Stilling has constructed chromo-lithographic tables which depend upon the fact that the color-blind are not able to distinguish two colors quite different to the normal observer if these lie on the same side of the neutral band in his dichromic spectrum and have the same brightness. His table 2, for example, consists of red letters on a brown ground, which cannot be deciphered by a red-blind person. They are, however, open to the objection that if the two colors do not happen to suit the patient's individual peculiarity the letters will still be recognized by him. Stilling then constructed ten plates, each plate containing four squares, and arranged in such a manner that the squares of one color form letters and figures and those of the confusion color the groundwork. This test plate is held in a good light and the candidate required to distinguish the letters or figures. An important feature of this test is that there is no inquiry as to color, but only as to letters and figures.

Colored lanterns have been used by Holmgren, Welsh, Edridge-Green and others, and this method has certain qualities which especially commend its employment in certain classes of patients. Particularly in the case of railroad employees is this method adaptable, as, with the use of a properly constructed lantern, like the one devised by Edridge-Green, for instance, the candidate may be made to look at the different signal colors as they would appear under the varying influences of atmosphere, brilliancy or distance. See **Color blindness, Lantern test for.**

Among the tests for color blindness pseudo-isochromatic methods have occupied a first place. If cases of color blindness were identical these methods would be more reliable than they are. Cases of color blindness however differ; in fact, it is difficult to find two cases exactly alike. If a pseudo-isochromatic match be found for one dichromic and letters of the one color be printed on a background of the confusion

color he will nót be able to read them. Another dichromic, however, may be able to read these letters quite easily. For instance, he may have much greater shortening of the red end of the spectrum, and the subtraction of the red rays from one color will make that color much darker than the other color of confusion. On account of the fact that simultaneous contrast is increased in the color blind, it is necessary that both colors of confusion should correspond to two points well within the monochromatic regions of the observer. These are the main objections to pseudo-isochromatic tables if we exclude the extreme difficulty of accurately producing them. Quite apart from this the fact that the two colors are regarded as identical by the color blind can be utilized in a far easier and more satisfactory manner.

If we have a number of colored objects in which the confusion colors of the color blind are accurately represented, the color blind by classifying or applying the same name to colored objects which are plainly discriminated by the normal sighted as dissimilar immediately betray their defect.

Edridge-Green's classification test, while not intended to replace his lantern, forms a ready means of detecting the color blind. The test consists of a number of colored beads in which every variety of confusion color of the color blind is well represented, and a box with four compartments into which the beads can be dropped. The aperture to each of the compartments is such that the observer cannot see the bead after it has been dropped into the box. The four compartments of the box are labeled red, yellow, green and blue.

The examinee is told to pick out from the beads in front of him, which are placed on the white porcelain lining of the box, all those that are red, keeping as nearly as possible to the exact hue but selecting those that are lighter or darker of the same color, and to drop them one by one into the compartment labeled red. He then goes through the same process with the three other colors; he is not allowed to compare the colors directly but must select them entirely according to the name which he gives to the color. It will be found that while the normal sighted are able to select the correct colors with the greatest ease, the color blind will make their characteristic mistakes. This test, like the lantern, will detect cases of color scotoma as well as those of ordinary color blindness.

Donders' pseudo-isochromatic patterns. Worsted patterns, which are pseudo-isochromatic to the color-blind person, are wound around a piece of wood in striped patterns, and the patient is asked to count the stripes. The stripes have the thickness of two threads of worsted. With this method three kinds of pattern are obtained: one which is

not, or only with difficulty, recognized by those red or green-blind; a second one, the stripes of which are easily recognized by the red-blind, but with difficulty or not at all by the green-blind; and a third one, the stripes of which are easily seen by those green-blind, but with difficulty or not at all by the red-blind.

Simultaneous contrast tests. Colored shadows. If a white and a colored light are allowed to fall simultaneously on a colorless surface and some object—a lead-pencil—be placed between this surface and the two lights, one of the two shadows which are cast upon the surface will appear of the same color as the colored light and the other of its complementary color. If a colored light only is used, the shadow cast will appear of the complementary color of the light. Thus, a red light will throw a green shadow, a blue light a yellow shadow. To the color-blind, the shadow appears uncolored, black or gray. The experiments can be so perfected that by regulating the light the contrast shadows appear stronger or weaker according to the intensity of the lights. This test cannot be recommended for examinations on a large scale, because the persons to be examined, even if they should perceive no colored shadow, may guess the color. Therefore, a large number of shadows would have to be cast,—red, green, etc.—when a color-blind person who sees them all colorless, would not always guess correctly.

Meyers' tissue-paper test. Meyers' test consists of a square of red paper with a gray border, the whole covered with a piece of tissue-paper. To the normal eye the border appears green—complementary to the color of the square. A color-blind person who does not recognize the color of the square, will not be able to tell the complementary color of the border.

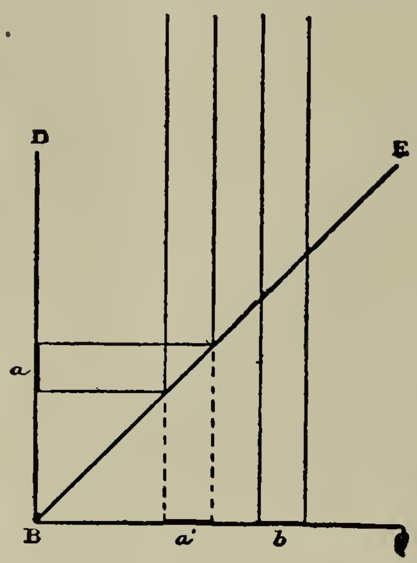
Pflüger's tissue-paper test. Pflüger has modified Meyers's test by using letters of gray or black paper laid on colored grounds, with tissue-paper covering. The letters appear in the complementary color. Black print on a red ground appears green; on a yellow ground, blue; on a green ground, purple; on a blue ground, yellowish brown; on a violet ground, yellowish green.

Contrast experiment of Ragona Scina. In bright daylight we take a strip of thick white paper which is folded in the middle at right angles, with a blot of ink on both inner halves, and some colored glasses. If the right angle is divided into halves by a red-glass plate and we look at the glass from above, the one spot appears red by reflection, the other bluish green by refraction. Color-blind persons do not perceive the contrast color, but call the green spot blackish or bluish black.

SPECIAL TESTS

The spectroscope. The spectroscope, while a valuable aid to the scientific study of color-blindness, is not a satisfactory test for everyday use. It is of service as an auxiliary test to be used by the expert.

Browning's pocket spectroscope consists of a compound direct-vision prism placed in a sliding tube, at one end of which there is a lens and at the opposite end a slit to admit the light. By the aid of this instrument the color-blind can tell us whether the spectrum appears shortened, and what colors he sees. The ordinary red-green-blind



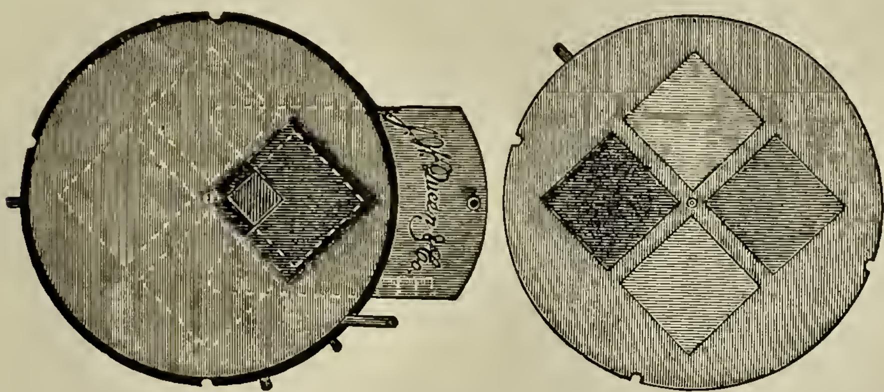
Experiment of Ragona Scina.

person sees but two colors, yellow and blue, with a gray or neutral band between them. Violet is usually designated as blue, and there is a shortening of the left end of the spectrum when the intensity of the light is diminished.

Polariscope. The polariscope consists essentially of two parts: a quartz plate for polarizing the light (polarizer) and a Nicol prism for exhibiting the fact of light having undergone polarization (analyzer). If the quartz plate be very thin (between the twentieth and sixtieth of an inch) and of uniform thickness, the light transmitted through the Nicol prism will be of a uniform tint, say, for instance, red. If the prism be slowly turned the disc of red light will change

through all the tints of the spectrum. If a double-refracting prism be used as analyzer two color-discs are seen, each of which goes through the same changes of color and intensity as the single disc. The candidate is requested to turn the prism until the two discs become of the same tint, and the angle is noted. The color-blind individual is unable to match the discs, and declares two dissimilar discs to be the same. While all these methods allow only of the determination of the color-perception *qualitatively*, there are other tests by which the color-sense can be tested *quantitatively*.

Donders' lantern consists of a blackened cylinder, with a circular disc containing a red, blue, green, and white glass. In front of the light is placed a metallic slide with perforations ranging from 1 to 20



Color-sense Measure (Oliver).

millimeters in diameter. Having tested and recorded the average size of the opening required by the normal eye to distinguish each color at 5 metres, the candidate is placed at this distance and is asked to name the colors as the disc rotates in front of the flame. If he recognizes the red light through the 1-millimetre opening, his color-sense is normal, $= 1/1$. If an opening of 20 millimetres is needed, his color-sense is $1/20$. If he fail to recognize the color through the largest opening he is told to approach the light slowly, and if he sees it at 1 metre his color-sense is $1/100$, etc.

Oliver's color-sense measure. (See figure.) This instrument consists of a blackened perforated disc in which there is inserted a movable, graduated slide. The disc is bolted to two circular cards, upon which are placed the three primary colors and blue and a series of confusion-colors. The disc is placed at 5 metres distance, in a good light, and the candidate requested to name the color. By raising the graduated slide the amount of surface exposure is increased until the color is recognized. At this point we refer to the slide, read off the size of the opening, and record the color sense as under the Donders'

lantern test. Oliver found that red requires $2\frac{2}{3}$ millimetres of surface exposure to be properly recognized by the normal eye at 5 metres distance; yellow, a slightly increased area; blue, $8\frac{3}{4}$ millimetres; green, $10\frac{3}{4}$ millimetres; and violet, $22\frac{3}{4}$ millimetres. It was also noticed that orange and violet were especially difficult to distinguish, and that the individual limit of color-perception varies considerably in healthy eyes.

Buxton's telechrome is a combination of the worsted and lantern tests. The contrivance is fitted with disc-carrying glass plates, which by gas-light show the following colors: pale grass-green, pale rose, bright red, bright blue, signal green, and yellow. The instrument is placed in a darkened room fifteen feet from the patient, who remains in the daylight and matches the test skeins with the colors as they are displayed in the lantern, under varying degrees of light intensity.

Color-blindness of the congenital type is never acquired, therefore it can only be the acquired form that can appear in an individual who has once successfully passed a carefully conducted examination for color-blindness. As abuse of tobacco and alcohol, concussion of the brain, cerebral disease, diabetes mellitus, albuminuria, syphilis, rheumatism, and even some acute fevers, may produce color-blindness, it seems necessary that railroad employees and mariners should be re-tested from time to time, say every third year. In doubtful cases, especially of young men, an ophthalmic examination of the central and peripheral color-vision ought not to be omitted. Not only the employees, but also the tests used for the detection of color-blindness, as well as the colors of the signals used, should be re-examined from time to time by a scientific expert, not only to protect the public properly, but also to insure justice to the men.

Much of the confusion which has arisen in the attempt to rightly designate the primary colors, has been caused by trying to build up a primary color by mixing lights which were already complex. Since the composition of these complex lights has been hitherto indefinable, the evidence on the subject is somewhat conflicting, and has given rise to a number of theories as to how many primary colors there really are in a continuous spectrum. The following list of theories as described by Lovibond will suffice to illustrate the confusion which exists on the subject:

A three-ray theory, consisting of red, yellow, and blue.

A three-ray theory, consisting of red, green, and violet.

A four-ray theory, consisting of red, yellow, green, and blue.

A five-ray theory, consisting of red, yellow, green, blue, and violet.

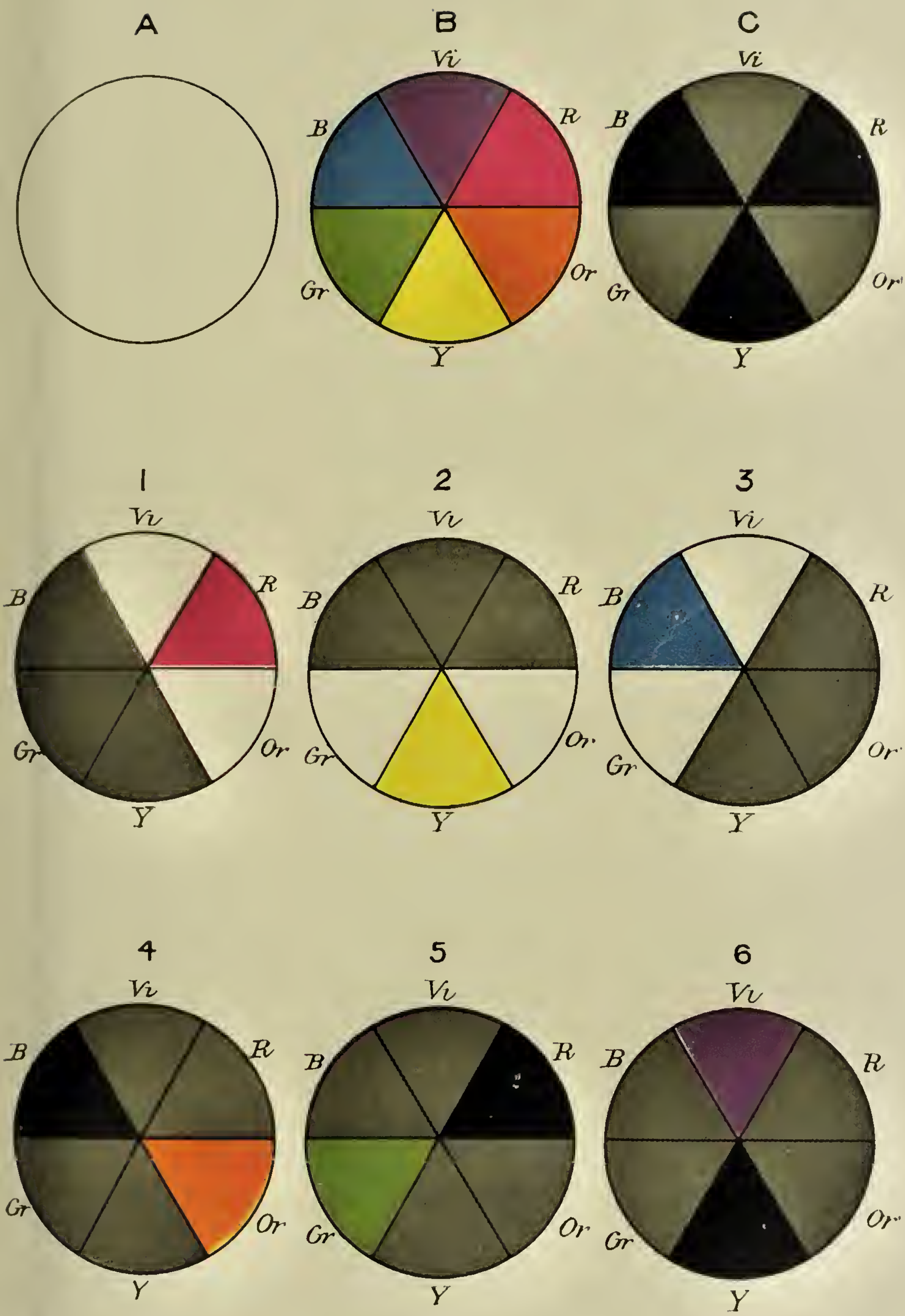


Figure to Illustrate the Destruction of Light and Color by Mutual Absorption of the Six Color Rays, in Suitable Combinations of Red, Yellow, and Blue.

A six-ray theory, consisting of red, orange, yellow, green, blue, and violet.

A seven-ray theory, consisting of red, orange, yellow, green, blue, indigo, and violet.

The experimental work which follows, carried out by means of carefully selected red, yellow, and blue glass, and illustrated by a series of color circles, defines the number of separate colors in the spectrum as being six, namely:

Structurally trichromatic, visually monochromatic — called the three **Dominants.**	→ RED	
	ORANGE ←	Structurally and visually monochromatic — called the three **Subordinates.**
	→ YELLOW	
	GREEN ←	
	→ BLUE	
	VIOLET ←	

The above six are divisible into two classes, one class containing the colors red, yellow, and blue. These colors as transmitted through the separate colored glasses, are alike in being visually monochromatic and structurally trichromatic. These Lovibond proposes to call the *dominant* colors, because each color masks its two accompanying rays.

The other class contains orange, green, and violet, which are the colors transmitted by pairs of the above glasses, and are alike in being monochromatic, both structurally and visually. These he called *subordinate* colors, because they only become evident as pairs of the dominants absorb each other. Since, by this method, they cannot be further disintegrated, orange, green, and violet may be here considered as the three primaries in the original sense of the word, not being divisible into other colors.

All light and color is destroyed by mutual absorption of the six color rays, in suitable combinations of red, yellow, and blue glass.

The specific action of each of the colored glasses on a beam of normal white light may be illustrated as follows:

Let circle A (see plate) represent a beam of normal white light, and circle B a similar beam, colored in six equal divisions to represent the six comprising color rays, and circle C a similar beam wholly absorbed by red, yellow, and blue glass of suitable and equal color values.

(The deeper shading in the red, yellow, and blue divisions is only intended to illustrate the double absorptions in these divisions, and not to signify incomplete absorption in the orange, green, and violet divisions.)

Circle 1 illustrates the effect of intercepting normal white light

with red glass, which absorbs the yellow, green, and blue rays, transmitting the violet, red, and orange rays, the red alone being visually color evident.

Circle 2 illustrates a similar beam as intercepted by yellow glass, which absorbs the blue, violet, and red rays, transmitting the orange, yellow, and green rays, the yellow alone being visually color evident.

Circle 3 illustrates a similar beam as intercepted by blue glass, which absorbs the red, orange, and yellow rays, transmitting the green, blue, and violet rays, the blue alone being visually color evident.

Circle 4 illustrates a similar beam as intercepted by red and yellow glass, showing orange as the color developed, all the other color rays being extinguished by mutual absorption.

Circle 5 illustrates a similar beam as intercepted by yellow and blue glass, showing green as the color developed, all the other color rays being extinguished by mutual absorption.

Circle 6 illustrates a similar beam as intercepted by blue and red glass, showing violet as the color developed, all the other color rays being extinguished by mutual absorption.

Another way of stating the phenomena illustrated in circles 4, 5, and 6, is by saying that, in each case, the color developed is the only one transmitted in common by the pairs of intercepting glasses.

The circle illustrations are intended to represent a normal white light of given intensity, and the intercepting glasses to show a color depth just sufficient to absorb all the color rays of the light, having in fact an equivalence of color-absorption value in reference to the normal white light.

It may be here stated that red, yellow, and blue glass are the only colors which lend themselves to systematic work, the use of any other colored glass leading to confusion.

It is not intended to affirm that the red, yellow, and blue rays may not prove to be structurally monochromatic, but only that, when met with in nature, they are structurally trichromatic.—(C. P. S.)

Color-sense and the emotions. It is claimed by certain observers that there exists a sort of relationship between the color-sense and the mental emotions of the individual. These observers maintain that the color-blind do not exhibit the same degree of keenness, or enthusiasm in their actions; that they have not the same thrill, the warmth and appeal in the voice, noticed in persons with a keen color-sense. These two distinct types were noticed by G. H. Taylor of Sydney (*Australian Medical Gazette*, July 6, 1912) among the criminals in the Darlinghurst gaol; the one class sombre and observant, the other bright and emotional. Among school-boys too he recognized a type

that was bright, joyous and emotionally restless, in contrast to a type in which, with an equally keen appreciation of its surroundings, there was a comparative absence of these conditions, which could not be explained by a difference either in intelligence or in the normal sense. In ordinary conversation, Taylor noticed, a color-blind person, if intelligent, frequently showed keen appreciation or resentment, he laughed or frowned, but it always appeared to be an appraisement by the mind. There was never evidence of the warmth and joy to be detected in a person with a keen color-sense. "I have lived with red-green blind persons," he says, "and have several intelligent friends who are red-green blind. I always noted and resented in them the absence of warmth and joyousness. One was musical and artistic, but I resented a want of warmth and appeal in his singing voice as also in his playing, although I now recognize that I craved for something which might not be included in the expression of the musician's idea. I notice in singers that the color face is associated with sympathy and thrill, and this is the quality which to a large extent arouses enthusiasm in an audience. A merely intellectual rendering of a song, however beautiful the voice may be, is entirely lacking in this quality. I notice in one case the presence, and in another the absence of what I refer to, in Madame Dolores and Madame Melba."—(C. P. S.)

Color-sense, Carter's test for. This is a test for the quantitative determination of the color-sense. The instrument, which must be used in a dark room, consists of an oblong box which has in the front side a collimator lens that makes the rays of light from a lamp enclosed in a separate box fall parallel on the opposite side of the little dark chamber, where a slide moves behind a round hole in this back wall. This slide is so arranged that different pigment colors either on a white or a blackened back-ground can be exposed to view; while the amount of light that falls on these colors is regulated by a changeable diaphragm, the opening of which can be made to vary from zero to one thousand square millimetres. There are also on the front side two sight-tubes, so that both examiner and patient may look at the same time. The physician first determines with what diaphragm he is just able to distinguish the different colors on the slide; then the patient does the same for his eyes. At the outside of the box there is an index that registers the side of the square diaphragm used, in millimetres. Suppose the examiner has to use under the existing conditions a square diaphragm of two millimetre's size and the patient one of three and a half millimetres size, then the color-sense of the

patient as compared with that of the surgeon would be $\frac{(2)^2}{(3.5)} = \frac{4}{12.35}$, or a little less than ⅓, as of course the color-sense, as stated before, is in inverse proportion to the amount of light necessary; and this quantity of light is directly proportional to the opening or the square of the side of the diaphragm used, the diaphragm retaining always the form of a square. While the instrument is thus used for reflected light, it can also be employed for transmitted light by using the colored glasses in the side, and letting the patient look at them from the opposite side as before.—(C. P. S.)

Color-sense, Direct. Direct vision for colors may be studied by placing the patient at a given distance from a chart or disc of graduated colors, and noting the amount of surface exposure which is required for the color to be properly recognized. In the scale of de Wecker and Masselon the colored surface, 2 cm. square, should be recognized at 5 m.; that is, the chromatic vision or V.C. or C.=1; if a colored test must be four times this size in order to be recognized, C=¼, etc.

Color-sense, Donders's test for. Rolls of pseudo-isochromatic wools were used by Donders in his method of testing for color-blindness. It is one of the many modifications of Holmgren's method. See **Color-sense and color-blindness.**

Color-sense, Eccentric. The condition of the functional activity of the eccentric portions of the retina, is best determined by the perimeter and by screen tests with white objects. The condition of the eccentric color-sense is also of interest, but from a diagnostic and prognostic point of view there is less information to be obtained by this means. Abnormal restrictions of the color field, it is true, are evidences of diminished visual acuteness: they are early symptoms of the lowering of conductivity. Color tests are also useful and of easy application for detecting the presence of a relative central scotoma in cases, for instance, of toxic amblyopia. But, according to Berry of Edinburgh, there is little use in any affection of mapping out the boundaries of the field for a number of differently colored objects—red, green, blue, and yellow, as is so often done. Even in the case of altogether normal eyes such a test leads to the discovery of not inconsiderable differences. The exact limits of recognition eccentrically of the color, apart from the colored object is not quite an easy matter. Very great care therefore is required to satisfy ones-self of the accuracy of statements made by patients. Apart from this practical objection Berry believes that, as generally applied, the tests for eccentric color vision are unnecessarily complicated owing to their being made on a wrong principle.

The physiological fact is lost sight of, he says, that the limits of the field of vision for any particular color are always the same as those for the color which is complementary to it. If it were not so, and it is not very difficult to prove that it is, a white object would not be seen uncolored over the whole of the field of vision. Consequently when one sees stated or charted that the green field in any case is narrower than the red, or *vice versa,* one knows that the colors used are not complementary, or at all events have not the same neutral or white value. Only one color should therefore as a rule be used for clinical purposes, preferably a red or a green. The exact color chosen, too, should be one which retains its hue in every part of the field for which it is visible. Another color, yellow or blue, whose particular hue, as seen eccentrically, is in the same way invariable, may occasionally be required, when the red or green object, either as the result of disease or of congenital color confusion (so-called color-blindness) is altogether unrecognizable eccentrically.—*The Lancet,* Oct. 25, 1913.—(C. P. S.)

Color-sense, Feeble. Weak chromatic sense. In the examination of a person for his color-sense, as for example by the Holmgren method, if the patient places with the test skein confusion colors—that is to say, finds that they resemble the test-color—then he is color-blind; while if he evinces a manifest disposition to do so, though he does not absolutely do so, he has a feeble chromatic sense. See **Color-sense and color-blindness.**

Color-sense in animals. The sense of color in animals was at one time regarded as mythical, but a clearer knowledge of animals and their habits has taught observers that it is by no means the imaginary attribute that many have claimed.

Dahl (*Scrapbook,* Feb., 1907) says that even among skeptics there are few who would question the effect of red on a bull, and insects are also attracted by it, though it does not rouse in them such a pugnacious spirit. A bumble bee will follow and hover over a red gown or parasol in the most persistent fashion, alighting if the opportunity is given him, and showing the greatest interest. The hypothesis that the *sense of color is possessed in a high degree by animals, and especially by birds,* furnished a basis for some of the most beautiful of the Darwinian theories of sexual selection.

No Darwinist doubts that the brilliant colors of the male birds of some species are destined to attract the attention of the female birds, and this presupposes naturally on the part of these birds a fine sense of color. Wallace has asserted that to the fact that certain plants bear fruit of brilliant colors is due their preservation; animals,

attracted by these colors, break the fruits from the trees or plants, carry them off, and thus indirectly assist in the dissemination of the seeds which they contain over large tracts of land. And this function of selection on the part of animals presupposes in them a certain sense of color.

Dahl relates some interesting experiments which he made with a monkey. He colored some sweets with a certain colored dye, and some bitter substances with that of another color, and declares that after a few attempts the monkey learned to leave, without even tasting, those articles of food which were colored with the dye and which indicated bitter-tasting substances, and seized at once upon those which indicated sweets. Varying the experiments sufficiently, he found that the monkey distinguished all the different colors readily, save only dark blue. Dahl calls attention to the fact that Mayer has stated that many savage tribes cannot distinguish dark blue from black, and that even children distinguish this color later than all others.

As a further contribution to this subject (which Herman Müller, Wm. Lessing, Plateau, Hess and others have fully discussed) Lovell (*American Naturalist,* 44, Nov., 1910) reports numerous experiments for the purpose of determining the *color-sense of bees.* German and Italian honey-bees, wasps and flies were exposed to glass slides backed with white and colored papers on which a central drop or line of honey had been placed.

These experiments were supplemented by the use of flowers and by an account of the behavior of honey-bees housed in hives variously painted. The paper establishes quite clearly the fact that bees can distinguish between the color of papers, flowers and painted hives, and that the form-sense (visual acuity) aids rather than constitutes the chief means by which they perform their duties of honey-collecting. They also learn to *discriminate* between form and color when they find it is of advantage for them to do so.

Lovell discusses some of the psychological questions that naturally arise during such an investigation. He remarks, for example, that to those not familiar with the habits of bees, "it will occasion surprise that the bee after it had discovered and began sucking honey on the red slide (to take for illustration the ninth visit of the first experiment) should have voluntarily left it and gone back to the blue for the larger part of its load. But its behavior in this instance is quite in accord with the principles of bee psychology. Bees, as Forel states as the result of his own and the experience of Huber, Buttel-Reepen and Wasmann, very rapidly form habits, and their attention becoming fixed by frequent repetitions is not easily diverted. When the bee.

which had been trained to visit the blue slide, alighted on the red, it was disturbed by the difference of hue and suffered a certain degree of mental disquietude, which was not allayed until it returned to the blue."

Lovell concludes that bees easily distinguish colors, whether they are artificial (paints, dyes, etc.) or natural ("chlorophyl") colors. Bees are more strongly influenced by a colored slide than by one without color. Bees, which have been accustomed to visit a certain color, tend to return to it habitually—they exhibit color fidelity. See, also, **Comparative ophthalmology.**

Color-sense, Oliver's test for the. This instrument, which is used for measuring the color-sense, consists of a perforated disc of blackened zinc in which there is inserted a movable graduated slide made of dead-black vulcanite, the disc being bolted to three circular cards upon which are known areas of color. By rotation of these color-bearing cards, and movement of the slide, any definite amount of color-exposure may be made. By means of an ingenious scale upon the slide, the amount of exposed color-area (from one to ninety millimetres square) can be seen at a glance. The color-cards have upon them adaptations for both reflected and transmitted light.

Color-sense, Reduced. There are two varieties of derangements of the perception of colors; the one characterized by an absence of the power to perceive colors, or *achromatopsia;* and the other characterized by difficulty in distinguishing colors, or *dyschromatopsia.* The former condition, or color-blindness is rarely total as a congenital defect. Generally it is *partial*—i. e. one or more of the fundamental colors are not recognized. In the second variety, or imperfection in the color-sense (reduced color-sense) the individual may correctly recognize brightly marked colors, but becomes confused in colors closely allied and in the various shades. To him violet and blue, and orange and red, are difficult distinctions. Dyschromatopsia should be distinguished from partial color-blindness. (Landolt).—(C. P. S.) See **Color-sense and color-blindness.**

Color-sense, Spectroscope test of the, Maitland Ramsay's. The instrument is designed to test the color-sense by means of pure spectral colors from a diffraction grating. It consists of a rectangular brass box 12½ inches long, 3 inches broad, and 1½ inches deep, mounted on a double metal support resting on a wooden base, and inclined at an angle convenient for ordinary vision.

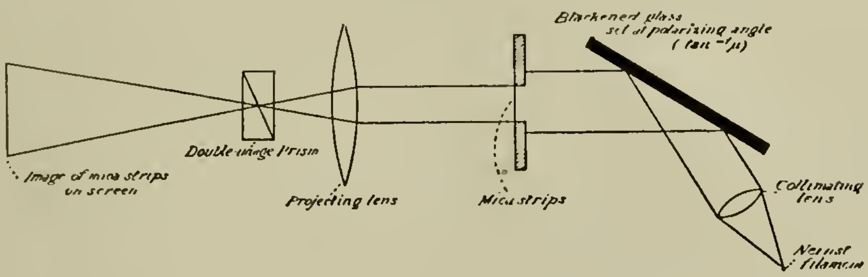
An eyepiece at the upper end, magnifying about ten times, has placed at its focus two diaphragms with slits which allow only one thin line of color to be visible in each. At the lower end light enters

through two slits which are protected from dust by a slip of ground glass, the width of the slits being graduated by means of adjustment screws. In this way the brilliancy of the spectrum can be diminished or increased at will, the difference being measured by the numbers on the graduated screw heads, which indicate tenths of a millimetre in the size of the slits. The interior of the box is carefully blackened, and in the middle is placed a diffraction grating, (containing 14438 lines to the inch) on either side of which is a collimating lens.

The result of the passage of a ray of light through the lower slits, the grating, and the lenses, is that two spectra of considerable dispersion are found in the focus of the eye-piece, the one above the other. Either or both spectra may be moved from side to side by moving shutters controlled by screws, the degree of movement being shown on two dials at the lower part of the instrument, which are graduated in wave lengths, and also marked with the chief lines of the spectrum. The examiner having set a definite color over one of the slits the patient is instructed to move the spectrum opposite the other slit by means of the screw until he finds the color which he thinks corresponds to the one fixed as the test. The indices on the dial are watched in order to ascertain the degree of correctness of the matching. At the upper end of the box is a rotary diaphragm perforated by three circular apertures, any one of which can be turned into position in place of one of the slits. When seen through the eye-piece, the diameters of the circles are equivalent to one, two, and four mm. respectively. This arrangement, which permits only a single circular spot of color to be seen, enables the correct naming of the colors to be tested as well as the correct matching. If a double-image prism be adjusted over the eye-piece, this spot of color is doubled, and by rotation of the prism, the second (or eccentric) color spot can be made to revolve around the stationary one, like a satellite round a planet, and this arrangement forms a convenient test for a central color scotoma. The source of illumination is an electric lamp. A simple projecting polariscope for use in testing color perception, as described by Tomlinson (*Trans. of the Ophthal. Soc. of the United Kingdom,* Vol. 31, 1911), consists of a piece of blackened glass mounted to rest vertically on the table of the Nernst lamp spectroscope. The light, parallelized by the lens of the lantern, is reflected from the blackened glass and passes through a preparation of eight strips of mica, and thence through a large lens which projects an image of the strips on a screen. In the focal plane of this lens is placed an Iceland spar double image prism which serves as the analyzer. A double image of the mica strips, yielding in all sixteen colored bands, is thus ob-

tained. The tints of these colors can be varied at will by rotating the analyzer, and further variation can be obtained by inclining the preparation to the path of light.

A practical and inexpensive contrivance has been devised by Zeeman and Weve (*Klin. Monatsbl. f. Augenheilk.*, April, 1911), for determining the color sense which combine the following advantages: Special colors and their admixture in all wave-lengths, saturation and intensity can be presented to the observer; they can be combined quan-



A Projecting Polariscope for Use in Testing Color Perception.

titatively with light of known intensity and wave-length; the examinee is always under the control of the examiner.—(C. P. S.)

Color-sense, Testing of. There are three plans for the recognition of subnormal color-perception: (1) direct comparison of pigment-colors, (2) direct comparison of spectral colors, and (3) the study of subjective after-color (complementary color). Of these, the first, for practical work, is the most worthy of consideration. The second method demands a certain amount of technical skill on the part of the examiner, and intelligence on the patient's part; the apparatus is expensive and liable to get out of order, hence this method is not much used in the popular sense. The third method is of value only in exceptional expert cases. See **Color-sense and color-blindness.**

Colors, Matching of. Some of the tests employed for the detection of color-blindness depend upon the principle of matching a given color with another one to be selected from a great number by the person examined. Here the naming is avoided, and the examiner can draw conclusions about the color-sense of the examinee by the color taken to match the first. Most of these tests use colored pigments in reflected or transmitted light, some use spectral colors, and some the subjective colors of successive or simultaneous contrast.

Colors, Naming of. It has long been held, especially by the school of Holmgren, that a test for congenital color-blindness which calls for the naming of the colors by the examinee, is a bad one and by no

means conclusive, as on the one hand the color-blind person may be able to name the colors used in the examination, having taught himself to give the usual names to the different shades, and on the other hand many a normal-eyed person may not succeed in giving the proper names to puzzling tints from confusion or ignorance. This test, however, is of use in acquired color-blindness, where the patient formerly had the full knowledge of colors, and where this method must be employed not only for direct vision, but also to obtain the field of vision for the different colors. As a test for *color-ignorance* (q. v.), it is very good, especially if the puzzling shades are avoided. Such a test to exclude color-ignorance is necessary, especially in navigation, where it is often requisite that the lookout-man should without a moment's delay pass to the officer in charge the name of the color of a light; because hesitation, whether caused by real color-ignorance or by want of knowledge of the proper word (from being a foreigner), might involve serious disaster.

Edridge-Green (*British Med. Journ.,* July 6, 1912) states that nothing has retarded the knowledge of the subject of color-blindness more than the statement (attributed to Holmgren) that in any test for color-blindness names were not to be used. He has never come across a man who was a candidate for an employment in which he had to distinguish between red and green light, and who on examination called green "red" and red "green" through color ignorance, and who was really able to distinguish between these colors and had a normal color sense. All the tests for color blindness which have been proposed during the last few years have been naming tests, and those who are best qualified to judge have recognized that the use of names is a necessity. There are, however, many who still adhere to the old statement that names should not be used, and the writer therefore analyzes the difference between matching and naming colors to show that the use of color names is a necessity and that no test for color-blindness can be efficient which ignores them.

Edridge-Green has been lately ascertaining the percentages of color-blindness in men, and finds that about 6 per cent. are definitely color-blind, whilst 25 per cent. have a diminished color perception compared with the other 75 per cent. The 6 per cent. when examined with his lantern made mistakes between the red, green and white lights, when they were clearly distinguished as different by the other 94 per cent., and any onlooker would say that they were rightly rejected, and it would not be safe for them to be in command of a ship in which it was necessary for them to distinguish between these three lights.

Many color-blind men will pick out the wools to match all five test colors as accurately and easily as a normal sighted person, so that, after a long, tedious examination he would not have suspected they were color-blind; but upon examination with his lantern, lasting less than half a minute, red has been called green, nothing or white; white has been called red or green, and green has been called red or white.

Colors, Natural. The first characteristic of any color is its *hue,* which tells us whether the color is red, green, blue, etc. This, in the spectral colors, depends physically upon the wave-length of the ethereal vibrations in each ray, and thus we can use the two terms hue and wave-length promiscuously when we have to do with spectral colors. But we have rarely to do with spectral colors; mostly the natural colors are made up of several rays or groups of rays, and then we can compare the resulting color-sensation with the nearest spectral color of a definite wave-length, or for purple and white with the nearest combination of two spectral colors, and thus define the hue.

Colors of Benham's top. This interesting toy is intended to be used in experiments by flashing light. For a full description of the top see **Benham's spectrum top,** on page 931, volume II, of this *Encyclopedia.* Percival considered that the phenomena observed with this top support the theory of Young-Helmholtz in regard to color-vision. He quoted from a paper by G. N. Stewart in the *Proceedings of the Royal Society of Edinburgh* for 1888, in which experiments were described in relation to Talbot's law, and he finds that there is no appreciable departure from this law even where the stimulus lasts only 1/8000000 of a second; and he also shows that where the stimulus acts a long time there is an excitation of all colors, giving the sensation of white; if on the other hand the stimulus acts for a shorter time then violet preponderates, and again if for a very short time the red color is more prominent. In connection with the colors seen in Benham's top Percival showed that the phenomenon depends on the irradiation of the surrounding white area over the edges of the black line, and the actual color produced is dependent on the rate and direction of rotation.

Colors of signals. Arguments have been advanced for a change of the colors used for signals. It is contended that as the great majority of people who are color-blind, are either red-blind or green-blind, these two colors are the ones which especially should not be used for signals. It is suggested that yellow and blue be substituted, as there are very few people who are either yellow-blind or blue-blind. Another advantage, it is pointed out, is that yellow is the most luminous color of the

spectrum. On the other hand, a blue glass, as commonly met with, transmits many red rays besides the blue ones, allowing four per cent. of the naked light behind it to pass through it, while by a glass of fairly pure blue the luminosity would be reduced to about two per cent. This luminosity in foggy weather would be reduced to nothing, a great danger in our times of high speed by land and water, where it is necessary to recognize the color of the light a few thousand feet away. A yellow signal would be luminous enough, but under certain circumstances would appear too much like white. Hence no good substitute can be found for the green which transmits from ten to twenty per cent. of the luminosity of the light behind it, whilst the red glass also allows about ten per cent. of the light behind it to pass through. Red, green, and white, then, seem to be the best signal colors for practical purposes, and cannot be replaced by others, where three signals are to be used; so that as the colors cannot be adapted to the color-blind, these latter ought not to be admitted to positions where quick and accurate distinction between red, green, and white is an absolute necessity. See **Color-sense and color-blindness.**

Colors, Primary. By the use of different combinations of red, green, and violet, we can produce all the color-sensations that the spectrum can give. Hence these three colors are called the primary, or fundamental colors. See **Color-sense and color-blindness.**

Color squares, Snydacker's. The addition of red and green squares to test charts, as suggested by Snydacker, affords a practical and rapid means of testing a patient's color perception. The smaller squares are of such a size as the average individual with normal color perception

Snydacker's Color Squares.

should be able to correctly differentiate at a distance of six metres (20 feet). Where an individual is unable to distinguish the larger ones at the above distance, we know that some pathological condition is present. When both the fundus of the eye and the vision are normal, and the patient is still unable to correctly name the color of the large squares, we know that one of two conditions must be present; either a patient is congenitally color blind, or a central scotoma for red and green is present. These color squares enable the oculist to at least roughly test each patient's central color sense at the same time and distance that he tests their visual acuity. This simple test will

often enable him to pick out certain patients who should have a further and more careful perimetric examination for anomalies that might otherwise have been overlooked.

Colors, Symbolism of. From the very earliest periods mankind has been accustomed (it would seem almost instinctively) to associate together the various principal colors with certain moods of thought and even with certain more or less definite ideas. The practice has been especially common in the Jewish and the Christian church. We shall here consider the subject, however, as a matter of convenience, under these two heads:

1. The color-symbolism of the Bible (both the Old Testament and the New).

2. The color-symbolism of the Christian church.

1. *The color-symbolism of the Bible. White.* This color, in the scriptures, stood for victory (Zech. vi. 3; Rev. vi. 2); for joy (Eccl. ix. 8); and, especially, for innocence (Mark xvi. 5; John xx. 12).

Black. Black, being the opposite of white, stood for despair and evil (Zech. vi. 2, 6; Rev. vi. 5).

Red. This was the color of blood and of courage. (As such, we may remark incidentally, it was the favorite color of the Indo-Germanic peoples.) (Zech. vi. 2; Rev. vi. 4, xii. 3.)

Purple. Symbolical of wealth, luxury and power. (Jer. x. 9; Ex. xxvii. 7; Rev. xvii. 4.)

Scarlet. This color was symbolical of sin. "Though thy sins be as scarlet."

White, blue, purple, and scarlet fabrics were extensively employed in the making of the curtains of the tabernacle and of the sacred vestments of the priests. Attempts, as a very natural consequence, have now and then been made, though not with much success, to attach to the use of these colors in this connection, some secondary significance. Into these attempts we need not enter.

2. *The color-symbolism of the Christian church.* In the early history of the church a set of rigid rules relating to colors and their uses was enforced on all such artists as attempted to depict sacred themes, persons, or objects. Later, such matters were left entirely to the judgment of the painter himself; but, even then, the old-time color-symbolism was often adhered to. Thus, the traitor Judas was almost invariably represented as wearing a yellow garment.

There are today in the Christian church five canonical, ecclesiastical or liturgical colors, *i. e.*, colors which are employed symbolically in the materials for vestments and for hangings. These colors, with their meanings, are (in the church of Rome) as follows:

White. As in the scriptures, the color of innocence and joy. It is used at marriages, and also at the festivals of saints not martyrs, of angels, of the Virgin, and of Christ.

Red. The color of blood. It is employed at Whitsuntide and also on the feasts of the Holy Cross and of Martyrs.

Violet and *purple.* These colors represent penitence. They are used at Advent and Septuagesima, on vigils and in Lent.

Green. The color of hope. Employed on numerous occasions at various periods of the year.

Black. The color of mourning. Used especially on Good Friday and at funerals.

In the Anglican church colors are not so freely used for vestments as in the church of Rome. They are, however, very frequently employed for hangings, and the symbolism, then, is very much the same.

The Greek church employs a number of colors symbolically, but (contrary to the practice of the Roman and Anglican churches) without especial reference to the calendar, except that, during Lent, red, with an obvious signification, is almost universally made use of.

The symbolism of precious stones is largely based on that of their respective colors. Thus, the pearl, being approximately white, stands for humility, purity, and innocence; the carbuncle, for blood and courage; the emerald, for hope.—(T. H. S.)

Color standards, Ashley's ceramic. These vary from buff to pure white and from bluish-white to pure white. They are obtained by mixing a white with a buff (or blue) clay in varying proportions (10:0, 9:1, 8:2) and represent nearly uniform shade steps. Such a series of standards may readily be calibrated with a simple reflection photometer in terms of coefficients of diffuse reflection. In using a photometer or a thin wedge of dark neutral glass to determine shades, color may be added to the white comparison standard or removed from the colored sample by interposing thin calibrated wedges of colored glass; in the first case of the same, in the second of the complementary hue. (Nutting.)—(C. P. S.)

Color standards, International. See **Color standards, Universal.**

Color standards, Ridgway's. These are used for determining and specifying the colors of *mat surfaces.* They consist in a set of 1025 colored cards embracing the whole gamut of hues and shades in just perceptible steps, all carefully adjusted by the color wheel. All these 1025 different colors, carefully adjusted on the color wheel, have been successfully reproduced in non-fugitive pigments and the collection is put out in book form. These standards, while arrived at by purely

empirical methods, are yet on a thoroughly scientific basis in that each separate reference standard differs in either hue or shade from its neighbors by but little more than the least perceptible wave length or intensity difference. For a full account of these color standards the reader is referred to *"Color Standards and Color Nomenclature,"* by Robert Ridgway, published by the author at Washington, D. C.

Color standards, Universal. In this age of universal standards we are even yet without generally accepted color units or a nomenclature having a scientific basis. Not only in America, but in England, France, and all other Continental countries, arbitrary names continue to be given to color shades and mixtures, without reference to their spectral or other values.

The advancement in the art of dyeing and the discovery of so many new shades and color combinations are the direct outcome of a study of modern chemistry; and yet the technology of dyeing and dye-stuffs is not comparable in definiteness with chemical terms. Even in formal treatises on stains, paints, and pigments, one occasionally sees such absurd color designations as "oriental drab," "apple blossom," "Nile green," "ashes of roses," "French gray," etc. The metrical system of weights and measures, the centigrade readings for the thermometer, the notation used in electrical measurements, and numerous other instances might be quoted as well known examples of the demand for and the supply of convenient and universal standards of measurement in various departments of the arts and sciences. Quite otherwise is it with chromatics. Even the most scientific and exact writer upon this and kindred subjects must continue, for want of something better, to employ the phraseology of the bargain counter and the penny paint-box.

There would not be so much room for criticism of this unscientific nomenclature if it were a constant one or if it were universal,—i. e. if it could be translated into color names in use in other countries. Such, however, is by no means the case. It is instructive to compare the color charts to be seen in the shops of German and French dealers with those exposed for sale in the artists' material stores of America. It will be found that each nation has its own more or less local and more or less fanciful names for color combinations—the new ones especially. Not only is this true of different countries, but differences in color nomenclature are often found in the catalogues of dealers in paints and dyes, as well as in color-cards issued by sellers of artists' materials, within the *same* country. The "terra-cotta" of one paint manufacturer is not necessarily the same color mixture sold by his

rivals in the same city. A comparison of the sample cards issued by representative firms in England, France, Germany, and this country, at once shows this. Hardly a color on the card of one firm is an exact reproduction of a color sample of any other. Thus a French firm's "Terre de Sienne brûlée," the German "Gebrannte Terre di Sienna," and the English and American "burnt Sienna," all contain varying proportions of red. In the same way the German "Elfenbein-schwarz" is blacker than the French "noir d'ivoire," while the English "ivory black" is pale when compared with either of these. Of the chemical constitution of that well known color "Van Dyck brown," Ludwig Fischer says: "This pigment consists for the most part of oxide of iron and aluminum silicate, and is often obtained by burning yellow ochre. *The color shade depends upon the amount of heat applied,* and these variations in tint have gained for it in commerce many names, such as Prussian red, English red, Neuremberg red, Roman ochre, Italian earth, red ochre, and ocre rouge. The genuine Van Dyck brown, which the artist whose name it bears loved to use, is said by him to have been prepared from deposits found in the neighborhood of Cassel."

The so-called "Schweinfurth green," has as many different names as variations in its yellow-green color. Fischer says it is known in the German paint-shops under at least twenty-one different designations. At least two investigators—Captain Abney and J. W. Lovibond, of England—have suggested a rational color measurement as part of an attempt to resolve all colors, shades, and tints, into terms of certain primary colors accepted as a standard. (See **Tintometer, Lovibond's** and **Color Patch Apparatus, Abney's**). At the request of Casey Wood (*Medicine,* March, 1896) the inventor of the tintometer measured a number of pigment samples selected at random from the stock of a large American color and paint manufacturer, with the following results of a few cases: The paint sold under the name of "primrose" was found to contain 1.16 red units, 2.9 yellow units, and .04 of the blue unit; the so-called "salmon" color equals 1.3 units of red, 2.7 of yellow, and 1.5 of blue; "lilac" equals red 1.85, yellow 1.7, and blue 3. units; "green stone" is composed of red 1.3, yellow 2.7, and blue 1.5 units; "apple-blossom" is composed of red 1.9, yellow .95, blue .8; "light blue" is composed of red .95, yellow 1.2, blue 4.9; "cream" comprises red 1.25, yellow 2.5, blue .04; "yellow stone," red 4.3, yellow 3.4, blue 1.5; "dark drab," red 6.2, yellow 7, blue 7; "extra light" drab, red 1.25, yellow 1.35, blue 2.8; "golden brown," red 7.4, yellow 7.4, blue 3.2.

The composition of a color might be written in the form of a

chemical formula; for instance, "golden brown" might be indicated as $R_{7 \cdot 4}$ $Y_{7 \cdot 4}$ $B_{3 \cdot 2}$. Many of these formulæ are capable of reduction to simpler terms, as Lovibond points out, but for all practical purposes it is perhaps as well to speak of them in terms of the primary colors accepted as standards. The purposes for which the tintometer is now used are numerous and embrace almost every department of the arts.

The amount and kind of adulteration in most foods and commercial products, as well as the impurities commonly found in drinking-water and other fluids, can be determined by the deviation, measured by the tintometer, from the normal tint of the pure article. Its color value is determined in a few minutes. Such chromometric examination is usually found to answer all the purposes of a quantitative analysis. In this way the tintometer is used to some extent by all sorts of commercial houses, and also in health departments of cities for the ready detection of impurities and adulterations in milk, water, beer and other foods. The slightest departure from purity, whether in food or any other product is at once shown by a measurable and corresponding variation in color.

The substitution of an exact color measurement for a chemical analysis is not new in physics. For example, the Bessemer process of converting iron into steel is almost entirely regulated by color changes observed in the furnace flame. It is exactly on this principle, except that the examination is made leisurely, that in a mixture or solution any departure from the standard, both as to kind and amount, is estimated by this instrument. When an exact color measurement has been made of a certain product (it matters not whether it be liquid or solid), the tintometer very readily shows whether a commercial sample is of equal purity.

To a limited extent chromometry has also been made use of in medicine for diagnostic purposes. In urinary analysis we have the Vogel scale of colors, where variations from the tint exhibited by normal urine are intended to indicate something of the chemical composition of that excretion. The best example, however, of the use of a chromometer as an aid to medical diagnosis is the hemoglobinometer, by which color changes in the blood, pointing to an excess or a diminution in certain important constituents, are measured by reference to a normal blood color taken as a standard.

A rather curious application of the tintometer has been made in a certain Agricultural Experiment Station where the value of fertilizers under examination is determined by the change in color produced in the leaves of certain plants whose growth was used as a test.

The degree of dryness as well as the amount of yellow, in samples

of white lead, can be accurately measured chromometrically, while the analysis of neutral waters is after a few trials made exceedingly simple, from the fact that the amount and kind of impurities in them bear a fixed relation to their color. So it is with flour, glucose, indigo, annatto, lard, butter, chlorophyl, steel, petroleum, wine, glycerine, and a hundred other articles of every-day production.

But quite apart from these practical applications of a color-measure to medicine and in the arts, it is to be hoped that some universal chromometric standard will finally be adopted, and so there will be added another to that long list of sciences whose technology is, in the widest sense, the common property of all scientific men.

Color-stick, Thomson's. This instrument for the examination of the color-sense was devised in 1880 by William Thomson, who had been trying for some time to find some way in which large numbers of railway employees could be examined with the least expenditure of both time and money, and at the same time efficiently. It is a modification of Holmgren's method, the test-colors to be matched being green, rose, and red. Thomson thus describes it: "The instrument consists of two flat sticks about two feet in length and one inch in width, fastened by a hinge at one end and connected by a button at the other. Between these, and concealed from view, are forty white buttons, having the figures from 1 to 40 clearly engraved on them, attached to the stick by small wire hooks, *which will permit of their easy removal or change of position.* To the eyes of these buttons are attached forty skeins of colored wool.

In obedience to Holmgren, the test skeins are three: 1, light green, A; 2, rose or purple, B; and 3, red, C. These skeins are shown to the persons examined in turns, and they are directed to select from the stick the colors which will match them.

On the stick the colors are arranged alternately to match the tests, and to be of those confusion-tints which experience shows to be most commonly selected by the color-blind. The first twenty tints, set A, are therefore green and gray and tan-colored confusion-tints, and this part suffices for detecting any color-blindness.

From 21 to 30, set B, the tints are alternately rose and blue, and from 31 to 40, set C, the tints are red, and its confusion-colors brown or sage, etc. It is arranged, however, that the real tints commence with figure 1 and range onward by the odd figures, while the confusion-tints are designated by the even figures, so that when the entire examination is concluded—in a case of normal sight—only odd figures should appear recorded on the blank, whilst if a fault has been made by a color-blind person, it will be revealed by the even numbers. In the

green test the appearance on the blank of numbers beyond 20 would be more than suspicious, with the rose anything below 21 or above 30, and with the red any number below 31. It will be seen that any superintendent or supervising expert could thus be sure of the presence or absence of color-blindness, by remembering the simple theory of the arrangement and scanning the blank on which the numbers of the tints selected had been recorded. The first twenty tints are green and its confusion-tints, but the color-blind has the whole forty to choose from, and does frequently select reds at the end of the series, and thus proclaim his defect. Again, of these confusion-tints, five are gray, and five are shades of brown, and we may thus guess at red- or green-blindness by the first mistakes of the color-blind,—the green-blind preferring the grays, and the red-blind selecting the browns.

In the rose-test, between 21 and 30, the green-blind frequently select greens in the first series, and thus show their defect."

Colors visible at night. According to experiments by army artillery-men on the Pacific Coast, black is the color least visible at night. The familiar ugly drab, or "war paint" of the American navy, was shown to be the most visible of all the colors tested, one boat so painted having been detected by the great sixty-inch search-lights at the entrance of Puget Sound, as far off as 17,000 yards.

Colors, Warm. Those at the red end of the spectrum.

Color-table, Daae's. The color-table of Daae is based upon the principle of Holmgren. It contains ten horizontal lines of seven little squares of colored wools each. Only in two lines (No. 8 and No. 10) are all the colors alike, being different shades of green and red. All the other lines contain different colors. If any of these other lines seem to consist of shades of the same color to any person, he is color-blind, the different lines indicating the different kinds of color-blindness. This table is very convenient; but in most cases a confirmatory examination by some other test will be required.—(C. P. S.) See **Color-sense and color-blindness.**

Color-table, Helmholtz's. If we compare the complementary quantities of red and blue-green, we notice that the red appears darker than the green. To illustrate facts of this kind on the table, Helmholtz supposed as equal quantities of two different colors quantities appearing to have the same brilliancy. He thus obtained the spectral curve illustrated in the figure. The small circle indicates the position of the white. Since the red complementary to the blue-green appears darker than the latter, we consider its quantity as smaller and place it consequently farther from the white.

Color-table, Maxwell's. On the table of Maxwell the greater part of the spectrum (from 0.63 μ in the orange-red, to 0.53 μ in the green, and from 0.51 μ in the green to 0.47 μ in the blue) is arranged on the

Color Table of Maxwell.

two sides of a triangle of which the green, between 0.53 μ and 0.51 μ, forms a rounded angle, while the extremities of the spectrum form two other somewhat irregular angles. We must imagine the third side of the triangle occupied by the purple colors, which are obtained by mixing red with blue. As nearly all the spectral colors have one of the coefficients negative, almost the entire curve is situated outside of the triangle of the *standard colors,* which indicates that the mixture colors have nearly all a little less purity than the spectral colors. The part situated between the red and the green coincides, however, very nearly with the corresponding side. By selecting another *standard color,* green, we could make the part of the curve situated between 0.51 μ and 0.47 μ coincide with the other side of the triangle, but it is easy to see that we cannot select the green color so as to make the two

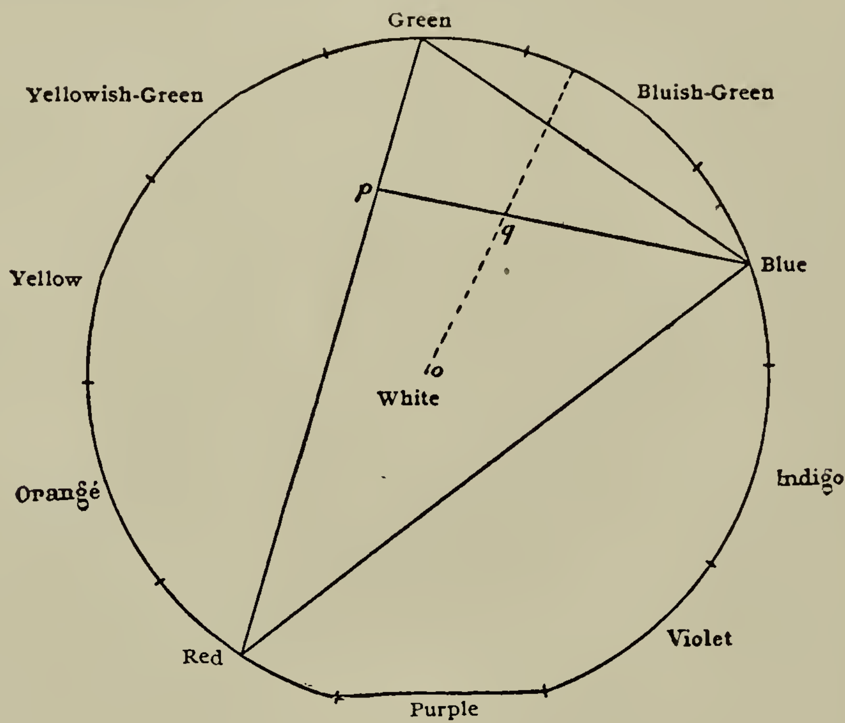
sides coincide with the curve at once. *We cannot, therefore, select three spectral colors* so that we can *reproduce all the other spectral colors exactly by their mixtures;* we can reproduce all the hues, but some of the mixture colors always continue to have less purity than the corresponding spectral colors, whatever may be the *standard colors* chosen.

By means of the table of Maxwell we can construct the result of mixtures of any colors. If we mix two colors placed on the same side of the approximately triangular curve, we obtain a mixture color which has as much purity as the spectral color, while if we mix two colors situated each on a different side, we obtain a mixture strongly diluted with white. The approximately triangular form of the curve, with the three colors red, green, and blue, placed at the angles, does not depend on the choice of the *standard colors.* By means of the equations of Maxwell, we can, by a simple calculation, express all the spectral colors by three colors other than his *standard colors,* for example by orange, blue-green, and blue. The curve even then retains its approximately triangular form, having the red, green, and blue at the angles, but it differs considerably from the equilateral triangle formed by the straight lines joining the three new *standard colors,* which indicates that the mixture colors have, in this case, very little purity. Maxwell selected red, green, and blue, so that the curve would come as near the triangle in form as possible.

The most interesting phenomenon among the great number of facts which are expressed by the table of Maxwell, is certainly this, that we can produce a perfect sensation of yellow by mixing red and green.—(C. P. S.)—See **Color-sense and color-blindness.**

Color-table, Newton's. Newton devised his table to give a graphic illustration of the results which are obtained by mixing colors. The principle of this table is that all the colors we can produce by mixing two given colors are placed on the straight line which joins these two colors, and so much nearer to that one of the two colors which enters most into the mixture. The quantity of the color of the mixture is expressed by the sum of the quantities of the component colors. Suppose, for example, that we want the result of the mixture of three parts of green with one part of red and two parts of blue. We begin by joining the green and red by a straight line, which is divided into two by the point p, so that the distance of p from the green may be a third of its distance from the red; p is then the place of the mixture of the green and the red, the mixture being represented by the number 4, the sum of the two component colors. We then join the point p

with the blue by a seeond straight line, whieh is divided into two by the point q, so that the distanee p q is the distanee of q from the blue, in the proportion of 2 to 4; q is the plaee of the mixture of the three eolors, and the quantity of this mixture is expressed by the number 6.



Color Table of Newton.

Drawing the line o q and prolongating it until it cuts the spectral curve, we see that the color of the mixture is a bluish-green strongly diluted with white.

There enters into this illustration of Newton an expression whieh is not defined, that of the *quantity* of the eolors. While it is easy to tell what must be expeeted from equal quantities of the same color, it is not easy to define the expression of equal quantities of two different colors, the result of whieh is that the form of the curve beeomes, up to a certain point, arbitrary. With Newton, we must consider as equal the quantities of two eomplementary eolors, whieh, when mixed, give white, sinee the white, on his table, is situated at an equal distance from both. If we take two other complementary colors, we must also consider as equal the quantities of these eolors whieh, mixed, give white, but on eondition that this white be of the same brightness as the former.

The table of Newton shows that, with the exception of purple, we

cannot produce new colors by mixing spectral colors, for we can always, after having found the position of the mixture, draw a straight line passing through the centre and this point. Prolonged, this straight line will meet a spectral color, and the mixture is equal to this color diluted with white.

The table of Newton indicates also another peculiarity of the normal color-sense, namely, the fact that we can reproduce all existing hues by mixing, two by two, three colors properly chosen. Let us select, for example, red, green, and blue, and draw on the table straight lines which join these colors. If, then, we select any spectral color, we can always join it to the centre of the table by a straight line; this straight line must necessarily cut one of the sides of the red-green-blue triangle, and at the place of intersection is found the mixture which is similar, in hue, to the spectral color. On account of this peculiarity the normal eye is called *trichromatic.*—(C. P. S.) See, also, **Color-sense and color-blindness.**

Color-table, Pseudo-isochromatic, of Stilling. In a mosaic of one hundred and forty-three small squares of the same color, but in many shades of this color, is placed a single letter, figure or other design, painted in a confusion-color. The color-blind are unable to recognize the letter. The collection of tables includes tests for the different forms of color-blindness; also for the detection of malingering. These tables were published by George Thieme, in Leipzig. See, also, **Color-sense and color-blindness.**

Color-table, Reuss's. One of the modifications of the Holmgren method for the examination of the color-sense.

Color terminology. At present the term *color* is used in a perfectly ambiguous sense; it is sometimes taken as including and sometimes as excluding the series of grays. The term is absolutely needed in the inclusive sense, and there is a simple means at hand by which to make it unambiguous—for color proper, there is no reason why we should not say *chroma.* We have already all its derivatives in common use, dichromatic, achromatic, tetrachromatic (for normal four-chroma vision). The Germans already discriminate between the *tones* and the *tone-less* colors, and we should be equally exact. For the whites (with their low intensities, the grays) we have at present no word indicating their quality; there is no reason why we should not make use of the term *achroma.* (The word is already in existence, in this sense, in the dictionaries of medical terms.) With these two names for the specific and the non-specific light-sensations, we have at once two good words for the *degree* in which each sensation-constituent is present in, say, a

grayish-blue; we can speak of its chromaticity and of its achromaticity. At present we have for these two perfectly definite sensation-characters only "degree of saturation," which is too vague, and "degree of non-saturation," which is very roundabout, and which, moreover, is a phrase that does not exist—at present this sensation character, though perfectly distinguishable, is not named.

There are four unitary (See **Color, Unitary**) colors proper, or chromas, and four series of color (chroma) blends. The words orange and purple should never be admitted into scientific speech—non-unitary colors should not be given unitary names. Just as there exist no unitary names for the yellow-greens and the blue-greens, so we should, in the other two series of color-blends, speak always of the red-blues and the red-yellows.

The term *brightness* has been thoroughly vitiated for scientific use by the color theory of Hering—his followers mean by it three things at once: (1) brightness in the real sense; (2) an assumed whiteness-constituent (though the color may be, for sensation, perfectly saturated); and (3) an imagined dissimilation-process which is taken to be its physiological correlate. Since it is impossible to rescue this word, at present, for its correct meaning, it is indispensable to discard it entirely. Its place should be taken by luminosity, or subjective intensity. Hering has said lately that those who can accept neither the psychological nor the physiological conceptions which lie at the base of his theory, may nevertheless be grateful for his terminology. But in fact his terminology, as regards "brightness" at least, is almost worse than his theory. His theory is, moreover, so bound up with his baseless terminology that the simple restitution of the term brightness, for instance, to its natural and unambiguous signification (subjective intensity or luminosity) would suffice, I have no doubt, completely to upset his theory. It is the surreptitious introduction of Hering's hypothesis as to the physiological substratum of brightness under this triply ambiguous term that permits one to be oblivious of the untenableness of the theory. A corrected color-terminology, therefore, far from being immaterial, is bound to have important logical consequences. Hess has proposed the fresh term *lamprosity*, which is also good.

Luminosity, subjective intensity, lamprosity, are terms indicating not quality but the degree of a quality. Hence to speak of the luminosity-spectrum, meaning the achromatic spectrum (*i. e.*, the distribution throughout the spectrum of the subjective intensities of the achromatic sensation) is to be very inexact; it is an error brought in with Hering's misconception of brightness.

"Pure" color should be discarded on account of its ambiguity; it sometimes means not blended with another chromatic sensation, and sometimes not blended with white. *Unitary* color is intended to mean not blended with either.

We shall, therefore, say that there are: *Four* chromatic sensations, *five* color (light) sensations, but *six* visual sensations.

TABLE OF PROPOSED COLOR TERMINOLOGY.

VISUAL SENSATION

- Color (light) sensation
  - Achromatic sensations, or achromas
  - Chromatic sensations, or chromas
    - Unitary colors: red, yellow, green, blue (white)
    - Non-unitary colors, or color-blends: yellowish-green, grayish-greenish, blue, *etc.*
- Black

Chromaticity and achromaticity will then mean the degree of blueness and of grayness respectively in a greyish blue.—(C. Ladd Franklin.)

Color test, Burch's. Burch has called attention to the fact that the various tests which depend upon painted letters or figures are unreliable as used in the ordinary way, because the colors are liable to change with time; it may be only slightly, but sufficient to spoil the test. Even the direction of brush marks permitted the recognition of the letters, when the light fell on them at a certain angle. To prevent this, Burch has placed the test in a box, where it is looked at through a convex lens that prevents accurate focusing, a perforated zinc plate being placed at the focus of the lens. He suggests that with paints of the right colors, new tests can be quickly prepared for any individual case. This he thinks important because it is astonishing how soon the exact description of a test card becomes known, if many people from the same neighborhood are to be tested.—(C. P. S.) See **Color-sense and color-blindness.**

Color test, Dunn's. An appliance for testing color-vision, devised by

Percy Dunn of London, consists of a dead-black metal screen fourteen cm. in height and nine cm. in width, supported on two metal cross-bars. Just above the centre of the screen there is an oval aperture about three cm. in diameter; around the lower half of the aperture is fixed a double groove, similar to that in a trial spectacle frame, for the purpose of carrying the colored discs and diaphragms employed in the test. In addition to the above there are four colored mounted glass discs, blue, red, green, and yellow respectively, one ground-glass disc, one smoke-glass disc, and three black vulcanite discs having central apertures, the diameters of which have been designed approximately to test the acuteness of the color-vision at varying distances of 100, 300, and 500 yards. There is also a card upon which appear four squares colored to correspond with the four colored discs.

The method of using the test is as follows: The screen is placed upon a convenient table with a light behind it, the candidate to be examined is to be seated upon a chair at four metres' distance. In the candidate's hand is placed the card with colored squares. One of the colored discs is then inserted in front of the aperture in the screen and the candidate is first asked to name the color and next to point to it on the card. The remaining colors are similarly tested. Lastly, the acuteness of color-vision is further inquired into by inserting the vulcanite diaphragms in front of the colored discs. The ground-glass and the smoke-glass discs are for the purpose of delineating misty and foggy atmospheric conditions.

Color tests. As will be seen by a perusal of the pages of this *Encyclopedia,* under the various **Color** headings, many methods for detecting color-blindness have been devised. Some are of value in determining the color-sense for some vocations in life, but are comparatively worthless for others. Thus, for those employed in mixing and matching colors, as workers in textile establishments, in pigments, etc., the selection and contrast tests are sufficient, while for those who must recognize colored signals other tests must be employed.

In testing the color-sense, it should be remembered that the patient is usually interested in avoiding the finding of any defect, and that he will use every artifice to avoid detection. It must also be remembered that the color-blind can often name colors correctly even when his color-sense is defective.

The tests for color-blindness may be divided into selection tests, contrast tests, and pseudo-isochromatic tests. See **Color-sense and color-blindness.**

Color-testing lamp, Middleton's. This is a simply arranged test, consisting of an asbestos chimney equipped with iris diaphragm, giving

any opening from 5 to 25 millimeters, and two cells permitting the use of colored glasses from the regular trial-case size.

Color test, Sauvineau's centesimal. Sauvineau (*Annales d'Oculistique,* July, 1908) describes his method of quantitative determination of the central vision for colors and measurement of central scotomata in railway employees and other artisans. He makes use of the lantern. The distinguishing feature of his method is that the diaphragms through which the different colors are viewed bear a definite relation in point of area to each other. In Sauvineau's scale there is a 10 per cent. difference.

It was found from an examination of 150 patients with normal or corrected vision that the majority could perceive red, yellow, green, and blue light from a lantern 5 metres distant placed in a darkened chamber (the patients being in ordinary daylight) when the diaphragm through which the light was visible was 1 mm. in diameter. There were some exceptions to this, notably when the test was blue light the diaphragm had to be larger, this color being less easily perceived than the others. Accordingly an opening of 1 mm. diameter was taken as the unit by which to measure quantitatively the patient's color-vision and a centesimal scale constructed from this.

The different diaphragms have a diameter measuring from 1 mm. to 10 mm. A patient who could only distinguish red light when the diaphragm was 10 mm. diameter could only have 1/10 vision for red possessed by a patient who could see this color through an opening of 1 mm. With a 3 mm. diaphragm the degree of color-vision would be 8/10. In Sauvineau's lantern the diaphragms are cut on a revolving disc so that they can be brought successively in front of the light. Between the diaphragm and the light is another disc carrying colored glasses, so that any desired color can be brought in front of the light. A third wheel carries mixed colors. For central scotomata, diaphragms smaller than 1 mm. are used. (*Oph. Review,* May, 1909.)

Color, Tone-value of. Attempts have been made to mix pigments with certain proportions of black and white, for the purpose of obtaining compounds possessing the two qualities of brightness and saturation, so that the colors may have the same value in terms of white, and that they may be readily recognized at the periphery of the field in the shades proper to them. This matter is fully discussed in Norris and Oliver's *System of Diseases of the Eye,* Vol. iv, p. 735.

It is a question whether it is theoretically possible to accomplish the desired result. It is not only very difficult to obtain pigment mixtures having a fixed color-value, but still more difficult to preserve the colors when once obtained; in the course of time they are prone to undergo

changes. Even supposing, however, that one could obtain pigments that are unalterable and that do possess a constant white value, the problem would still remain unsolved, because their (white) tone-value varies with the character of the illumination. Bull has justly observed that the result obtained by their employment depends upon the time of day and the intensity of the illumination. The fact that variations in the luminous intensity of the (white) tone-value of a color are influenced by the degrees of the illumination, results from the increased sensibility of the retina when the illumination is diminished. It affects unequally the different refracted rays. It has no influence upon pure red, but is marked in the case of the more refrangible colors, such as blue and violet. Moreover, this increase in retinal sensibility has a certain bearing on brighter illumination; the particular color thus rendered more luminous appears less saturated, and finally passes into white. Thus it is that the saturation of a color does not depend alone upon the proportion of white which it contains, but also upon the condition of the retina.

The practical value of these pigments will be determined by the curious fact that perimetric observations with them have shown that the field for red is just as large as that for green! This is certainly not the conclusion one arrives at in using spectral colors. The saturated pigments of commerce give results more in conformity with those obtained from simple rays.—(C. P. S.)

Color-top, Maxwell's. One of the various methods for studying the effect of mixing colors. This device is a flat top, on the surface of which discs of various colors may be placed. On rotating the disc rapidly *white* will be produced. Dancer has added to this top an improvement by which, even while the top is rotating rapidly and the sensation of a mixed color is strongly perceived, the eye may be able to see the simple colors of which it is composed. This is done by placing on the handle of the top, a short distance above the colored surface, a thin black disc, perforated by holes of various size and pattern, and weighted slightly on one side. In the rapid rotation of the top, the thin black disc vibrates to and fro, and in doing so breaks the continuity of the color impression; and thus the constituent colors are readily seen.

Color triangles, Lip's. A device used for the detection of color-blindness.

Color, Unitary. A color in which no other color (no slightest trace of any other color) can be detected. A non-unitary color, or a color-blend, is a color in which the presence of two colors can be detected. Most reds that one comes upon in nature people will agree upon as

being either slightly bluish or slightly yellowish,—it is an exception when one gets a red which is neither. So the colors of pigments (red papers, etc.) depend upon what dye-stuffs are accidentally at hand; reds are not put on the market for the purpose of being neither bluish nor yellowish, and hence the manufacturer of papers, silks, etc., does not seek for dye-stuffs which have this quality of not being in the least a color-blend. But with the aid of a rotating color-disc, one can correct this small amount of blueness or yellowness (whichever it may be) by adding a thin sector of the complementary color,—in this case either yellow or blue. By trial one can thus obtain, on the color wheel, a red which most observers will affirm to be a simple red, with no tinge of any other color—either of blue or of yellow. Some observers will be found to differ from the majority as to exactly what combination gives this particular red—it has been shown by Frl. K. v. Maltzew that there are distinct individual differences in the color sense,—but all will be able to *form the judgment* of *non-blendedness,* and the differences will be slight.

This judgment is much more easily formed if the observer is offered a row of eight or ten color-discs, just perceptibly different in color-tone one from another, and all near the color-tone required. The same observation can be made for each of the four elementary colors of the spectrum—a blue can be determined by this method which looks neither reddish nor greenish,—a green which looks neither bluish nor yellowish, and a yellow which looks neither greenish nor reddish. The judgment thus formed is based upon a purely psychological experience, and has nothing to do with, (1) the "fundamental" colors which may be adopted as the constituents of any color-theory—for instance, the so-called *Urfarben* of the Hering; nor, (2) with physical *mixtures* (or non-mixtures) of radiations of particular wave-lengths; nor, (3) with current color *names.* Hence a definite term is needed for the chromatic sensations which possess this character—much confusion will result if we do not clearly distinguish these four from the other classes of colors. Hence it will not do to call them fundamental colors, nor elementary colors, nor "principal" colors, nor primary colors. These terms all have reference to some *theory* of color. A distinct, and purely psychological, and non-ambiguous, term is needed for them, and for their opposites. It is absolutely necessary to restrict the term *color-mixture* to *physical* mixtures of *physical* light-rays. Hence for the psychological distinction between the two classes of chromatic sensations in question, we should use the terms: *Unitary colors* (the *exact* red, yellow, green and blue) and *non-unitary colors* or *color-blends* (the yellow-greens, the blue-greens, etc.). We cannot find an

orange in which there is no trace of red nor of yellow (for *every* orange, in spite of its unitary *name,* is at once red *and* yellow). Neither can we find a purple, in spite of its unitary name, which looks neither reddish nor bluish, for every purple is *both* reddish and bluish. On the other hand, no one could affirm that red *is* a purplish orange, in spite, again, of the unitary names of purple and of orange, though it is true that red *resembles* both purple and orange. The distinction could be expressed in the language of mathematics in this way: *Red* is a *common factor* of purple and orange, but purple is a *multiple* of red and blue. It has been found that the Esquimaux, whose color experiences come from the sunset sky and the autumn woods, and whose color language has not been vitiated by an interest in accidental dye-stuffs, never make use of any but non-unitary names for the non-unitary chroma-sensations. In this they are far more scientific than are other races. We owe our extremely unitary name, purple, to the beauty of a dye-stuff early extracted from a certain shell-fish.

It is very necessary to insist upon this reformed terminology, because the subject has been much obscured by some of the psychologists. See *Science,* Vol. 12, p. 408, and Baldwin's *Dict. of Phil. and Psychol.,* Art. *Vision.*

Every artist and many scientists will tell you that red and yellow and blue (or red and green and blue) are the "primary" *colors,* and they will mean many different things by that—all obscurely. Hence, the patent necessity for distinguishing between the *sensation*-characteristic of non-blendedness (unitariness) and the *physical-light* character of homogeneousness or non-homogeneousness. (Pigments do not reflect homogeneous light-rays, and hence such facts as that yellow and blue pigments, when mixed, will often produce green, are of no scientific interest.)—(C. Ladd Franklin.)

Color-vision. See **Color-sense and color-blindness**; as well as other captions beginning with the word **Color.**

Color-vision in the peripheral retina. The color of an object is not recognized at the very extreme part of our field of vision; everything makes the impression of gray. Deviations from normal color-vision similar to those observed in the color-blind, thus occur in the peripheral parts of the normal retina. As we approach the middle of the visual field the difference between blue and yellow is first recognized, though blue is usually seen a little more peripherally. In this yellow-blue zone deep red appears almost dark or dark-yellow, blue and leaf-green of a yellowish-white. Still nearer to the middle, red and green are also differentiated and recognized as such.

It is admitted that by practice our peripheral color-vision can be somewhat improved by a better education of the corresponding brain parts. The extent of the peripheral field for white and colors is given in the following table, from Norris and Oliver, Vol. I, p. 606:

	White	Blue	Red	Green
Externally	90°	80°	65°	50°
Out and up	60°	55°	45°	40°
Upward	45°	40°	35°	30°
Up and in	50°	45°	30°	25°
Internally	60°	55°	50°	40°
In and down	60°	50°	35°	30°
Downward	70°	60°	45°	35°
Down and out	85°	75°	55°	45°

In examining the color-fields it is necessary to take into consideration the degree of the general illumination, the brightness and the area of the color employed. Our peripheral color-vision depends also on the area of the colored object.—(C. P. S.)

Color-vision spectroscope, Edridge-Green's. This instrument is a great advance on his earlier spectroscope for the estimation of color-vision. It is constructed, and the adjustments of the instrument are so graduated, that readings can be taken direct from the instrument without the necessity for using calculation tables. In the focus of the instrument are two movable shutters, either of which is capable of moving across the spectrum. By means of the two shutters any given portion of the spectrum can be isolated. Each shutter is controlled by a drum graduated in wave lengths, so that the position of the edges of the shutters can be known. The accuracy of the graduation is to 5 Angstrom units. With this instrument it is possible to ascertain the exact size of portions of the spectrum which appear monochromatic and their varying size with different persons. It is also possible to determine the limits of variability on both sides of the spectrum, the exact size and position of the neutral band in different dichromies and the position of the most luminous portion of the spectrum. The same inventor has more recently introduced his color-perception spectrometer (q. v.), described elsewhere in this volume.

Color-vision, Theories of. The mediation of light sensations consists in a combined physico-physiologico-psychic chain of events. (Physiological events also are physical, of course, in the last analysis, but we may use the term *physical,* for the moment, in the sense of extra-corporeal, since there is no good term for that meaning.) We may also speak

of this series as a photo-chemico-psychic chain of events. The chemical portion of the series, however, is complex (fourfold at least): it consists of (1) a chemical dissociation by resonance in a light-sensitive substance, (2) a chemical nerve-excitation by certain products of this dissociation, (3) a nerve conduction (which is now supposed to be also chemical in its nature), and (4) a final cortical neural process, regarding which we know nothing.

Color theories are of three fundamental kinds: mechanical, chemical, electrical. Instances of mechanical theories are the original theory of Thomas Young, and the more recent ones of Charpentier, Patten, Stöhr. In all of these it is supposed that molar masses of matter—usually of microscopic size—fibrillæ or granules—are set into vibration by the action of light waves upon the retina. Charpentier, however, supposes that transverse vibrations of the free ends of the rods and cones constitute the nerve excitation required. But if any molar physiological structure (even any microscopical one) were to vibrate in tune with even the longest light wave it would need (Troland, *Am. Jour. of Physiology,* 32, 1913, p. 12) to possess a modulus of elasticity two hundred million times greater than that of hard-drawn steel. This is, of course a *reductio ad absurdum* of all theories of mechanical stimulation which depend upon resonance. Nothing but molecular systems are of the right magnitude to respond selectively to light. All theories which have any claim upon consideration are, therefore, at present, chemical theories,—and that is to say photochemical theories. (The Helmholtz theory, already in the second edition of the *Handbuch d. phys. Optik*—which was brought out by Helmholtz himself—posited distinctly three photochemical substances in each one of the elements of the bacillary layer, though the physicists still think that the Helmholtz theory involves response in three separate light-sense cells.) Attempts at theories of an electrical nature have been made by Stokes, Nicati, Peddie, Preyer, and Edridge-Green, but these are based upon electro-physiological phenomena, and it is quite certain at present that the actual retinal processes are of a photochemical character.

The photochemical theories which we shall here give especial attention to are those of Helmholtz and of Hering, and the more recent evolution theory, which aims to meet the requirements of the situation more adequately than that of Helmholtz, and with less violation of established scientific principles than that of Hering. It has lately been said, correctly, that "the scientific value of the Helmholtz theory is at the present time almost negligible,—it explains only the most rudimentary of the phenomena of visual sensation; and that

of Hering, in its pseudo chemical physiological and psychological aspects, is guilty of all manner of offense against fact and reason." . . . Derivatives of these theories (Troland, *loc. cit.,* pages 8, 9, 10. See references there to many theories) are to be found in the suppositions made by König, Ebbinghaus (this theory was soon found to be wholly inconsistent with newly discovered facts regarding the visual purple, and it was withdrawn by its author), G. E. Müller, Donders, Wundt, and v. Kries. Later attempts to account for color are those of Pauli, Bernstein, Brunner, and Schenck.

Before weighing, in brief, the various considerations which have bearing upon the claims of a color theory to provisional acceptance, it will be necessary to give a moment's attention to several important preliminary topics,—namely, current *photochemical conceptions,* the character of *subjective intensity* (*i. e.,* the luminosity of a chromatic or an achromatic experience), and to the *sensation of black.*

Photochemistry.—At present one knows nothing about what takes place in the retina when objective light is transformed into some form of nerve-excitation which is then in turn conveyed to higher nerve centres and becomes the final neural correlate to the subjective experience, color. This neuro-psychic event (to use the good phraseology of v. Bechterew) will have for its detailed explanation whatever explanation is current, among the physiologists at any given time, of similar events elsewhere in the nervous system—events of nerve-fibre conduction and of nerve-cell excitation. But the preliminary retinal process, by means of which the physical energy of magneto-electric vibrations (light) is transformed into some other form of energy (presumably chemical), which then causes the requisite nerve-excitation, is a subject which belongs to photochemistry, and in particular, to bio-photochemistry. It happens that photochemistry, even in its general form, is a subject about which extremely little real knowledge has been obtained. It is unfortunate for color-theorists that this is the case.

The chemists have been very negligent in that they have not already investigated the light-sensitive substances of the retina. Much is known, it is true, about the visual purple (a substance which occurs in the rods only), although it is not yet known whether it is the essential photochemical substance or whether it acts merely as a sensitizer. It is the photochemical substance in the cones, however, which is important, for it is certain that the cones mediate the chromatic sensations, while there is reason to think that the rods may be organs for achromatic sensations only. The visual purple is easily obtained in a condition of purity (it is soluble in gallic acid), but

the light-sensitive substance in the cones, whatever it may be, is colorless, and therefore less easily detected. But the fact that the cones can be obtained free from rods in the case of animals which have a fovea (since the fovea contains cones only) ought to make it comparatively easy to isolate the photochemical substance in question. No work has been done in this field, however, and hence the particular nature of the chemical process involved is at present a pure matter of hypothesis. But both the physical facts of light and the psychological facts of light-sensation are so complicated, and their mutual interconnections are so numerous and so definite, that if these facts be kept well in mind the indispensable characters of this intermediate chemical process can be laid down with a good deal of confidence. While, therefore, any color theory is at present necessarily hypothetical, nevertheless its essential logical conditions are, as we have said, so numerous (provided always the facts are taken account of)—in the language of the mathematician its "degrees of freedom" are so few—that any adequate theory will almost certainly constitute a logical framework into which farther research will merely need to fit in a greater amount of detail.

It will, however, be convenient to have before us the views of the chemists as to the nature of the chemical changes induced by light, so far as they have been at present made out: The synchronism between electro-magnetic radiations (light) and some constituent of any chemical substance which is affected by them (selective dissociation by light necessarily involves, of course, synchronous vibrations between the agents concerned) is now known to be an affair of the oscillations of a single electron or else of a group of electrons. The infra-red radiations of the spectrum (from $1/10\mu$ to $.002\mu$ in wave-length) are of atomic dimensions; but within the visible spectrum the rate of the vibrations (from .0001 $\mu\mu$ to .0007 $\mu\mu$ in wave-length) is such that only structures of sub-atomic dimensions can have their oscillations affected,—that is to say, electrons or groups of electrons. This increase in the amplitude of its oscillations will, (if the intensity of the light is sufficient) cause an electron (or a group of electrons) to be torn off from some atom, and that atom, as well as the electron torn off, has then become charged (a free electric charge develops). In this condition it has acquired a new valency and hence is prepared for a new chemical re-action; in the case before us it is now prepared to act chemically upon the optic nerve terminations.

Intensity.—The brightness of any color sensation blend (as of a whitish bluish green) is the same thing as its subjective intensity. The intensity of sensation in general is an *inseparable* conscious ele-

ment,—that is to say, an intensity does not occur except as the intensity *of* something; we cannot get intensities by themselves. In sensation in general, intensity is correlated with degree of excitation in central nerve cells, which in turn depends upon volume of chemical (or other) stimulation of the receptors. The conception brightness, as applied to color in ordinary life, is a perfectly definite one,—every one knows what is meant by it. But in the Hering theory, the conception brightness is hopelessly confused with the idea of an attendant whiteness sensation. That theory requires one to suppose that the most saturated possible spectral red owes its entire brightness, physiologically, to an accompanying whiteness process. There is no ground whatever for this belief; it is true that it is essential to the Hering theory; but the naïve way in which many psychologists utterly confound the Hering theory with established facts is unscientific to the last degree. Until a theory ceases to be hypothetical and becomes known to be true, it is very desirable, as an element of correct methodological procedure, to keep other possible explanations in mind. Yellow and blue are, for instance, not necessarily antagonistic physiological processes, nor are red and green: the facts of color are exactly as well stated when we say that yellow and blue are white-constitutive, and that red and green are yellow-constitutive. Until a theory of one or the other of these two types has been transformed into established fact (as the theory of molecules, atoms, elekrons, magnetons, is now taken to be established fact) it is scientifically wrong to commit one's self to the belief that the first of these ways of looking at this matter is necessarily true. Professor Chamberlain has advocated warmly, as indispensable scientific procedure, the keeping in mind of multiple hypotheses so long as the evidence demands them.

In order then to keep free from the shocking vitiating of color fact involved in Hering's theory of brightness, it is absolutely indispensable for the present to substitute for brightness the phrase *subjective intensity;* this can be done because the meaning in common life is exactly the same. On the theory which we are here discussing, subjective intensity, then, in color, will depend upon volume of cortical nerve excitation, and that in turn upon the concentration of the nerve excitant present in the retina. Thus the subjective intensity of, say, a spectral blue will be taken to be correlated with the volume of the blue-producing photochemical product involved, whatever that may be. This in turn will be regulated, loosely speaking, by the objective intensity of the light stimulus, that is to say, by the amplitude of the light waves. Any other interpretation of brightness in color than

this would be totally out of harmony with our conception of the physiological correlate of intensity in every other sensation region; consequently it would need to be established by very strong reasons, but the purely hypothetical view of Hering concerning the cause of intensity in color is established by no reasons whatever, save the psychological motive of desiring to keep this theory still in existence. Volume of photochemical decomposition is then, in this theory, the psychological correlate of "brightness" when any specified wave length varies in physical intensity; but the relative brightness of, say, a blue-producing and a green-producing wave length is not proportional to their respective physical energies but is purely specific in its nature. That is to say that, as in all cases of selective dissociation by light, effect of light rays from different portions of the spectrum cannot be predicted from anything in the physical nature of the light rays concerned.

Black.—The prominence which is given to this color-pair, black-white, is wholly pernicious. Black is not properly a co-term with white any more than it is with any of the specific achromatic sensations. Black is a background sensation against which all the color sensations (in the extended use of the term, including white) are projected; it is a subjective experience—it is the response made in consciousness to the *no-external-stimulus* condition of the retina. (It would be quite in accordance with current physiological views if, in the utter absence of knowledge on the subject, we were to say that it is a sensation attached to a nerve-excitation due to some specific internal secretion in the retina.) This is also the view of Wundt and, of course, of Helmholtz. One should note here the difference between an assumed physiological correlate for black (where nothing farther hangs upon it, and it may just as well be one thing as another) and that for the light (color) sensations, where the *inter-connections* of psychological fact (complementation, development, reduction to white-sensation in the several cases of (1) faint, (2) brief, (3) peripheral, (4) over-bright, (5) over-long, retinal stimulation) demand an hypothesis which works all together for a bewildering complex of fact. Response in consciousness is of a pragmatic character (if one must use the fashionable term for useful), and the prominence of any character in consciousness depends upon its *degree* of usefulness. When, in real life, we speak of the white-light sensation, we do not naturally think of it (if our thoughts have not been permeated with the Hering theory) as a black-white complex—although we can do so if we like. What is always present, and never changes, can easily slip out of consciousness, and out of speech. But at low degrees of

luminosity, when the black background forces itself more strongly upon consciousness, then, indeed, we may speak of the black-whites. (What a low degree of white light would look like if it were not projected upon this black background we shall never know.) But note that we have just as much occasion for speaking of the blue-blacks as of the white-blacks. Black is a discrete sensational experience, and it is no more closely associated with white than with blue. The Hering theory could easily be vastly improved if instead of assimilating a black-white series to the yellow-blue and the red-green series, which it does not in the least resemble (black and white are sensations which *do* occur together, which is just what the other two color-pairs are *not*), it assumed discrete and disconnected physiological processes for them. The black-white series is homologous to the green-blue, the red-yellow, etc., color-blends, and it is exactly *not* homologous to the yellow-blues nor to the red-greens, which are mutually extinguishing color-pairs. If this were done for the Hering theory, there would be nothing erroneous left in it except its view that the chroma co-pairs are antagonistic instead of complementary.

The development theory of color.—This theory takes into account the fact of a gradual evolution of the color sense from a primitive condition of achromatic vision such as still exists in the periphery of the retina and in the eyes of the totally color blind. It assumes that the achromatic sensation (white—what we call in its lower intensities gray) is occasioned when terminations of nerve-fibres undergo excitation by means of a chemical substance dissociated out, under the influence of light, from a primitive light-sensitive material, which very likely is the only such material which occurs in the rods. Whether it is identical with the visual purple, or whether that acts simply as a sensitizer, it is impossible at the present time to say. This may for convenience be designated as the gray substance. This substance responds, in this form, non-specifically to light from any portion of the spectrum (but most to light of wave-length $\lambda 505$). The cones, however, which are known to be structurally more highly developed rods, contain a light-sensitive substance which is of a more highly developed character in the sense that it is capable of responding specifically to the different rapidities of light-wave motion—certain atomic groups within the molecule are fitted to being broken off by the action of light of certain definite periods of vibration. This development may be supposed to have taken place in two successive stages in accordance with what is known of the actual development of the color-sense (bees, for instance, have yellow-blue vision only). The first of these stages consists in the formation of two groupings within the molecule, one of which is dissociated by the slower waves

and gives a sensation of yellow, and one of which is dissociated by the more rapid waves and gives a sensation of blue. This stage continues to exist in the mid-periphery of the normal human retina, and it alone is the condition present in all the cones throughout the retina in the eyes of the red-green, blind.

The next stage of development consists in the division of the yellow component into two fresh groupings in one of which the internal oscillations of electrons are of such a periodicity as to be affected by the longest visible waves, the red end of the spectrum, while the other group is dissociated by rays corresponding to the green of the spectrum, and gives rise to the sensation green. But if the red and the green groupings are dissociated out at the same time (if red light and green light impinge upon the retina together) then we have substances which (being the exact constituents of the former "yellow" component) unite chemically to produce that component (just as an acid and a base, for instance, would, when present together, unite to produce a different substance, a salt). In this way is accounted for the fact that red and green are never sensed together but that they always mutually extinguish each other and are replaced by the sensation yellow. In the same way whenever the yellow nerve excitant is present together with the blue nerve excitant they form a chemical union which is then identical with that original nerve excitant whose effect was the primitive sensation white.

This theory of color may seem at first sight to be somewhat complicated, but it will appear upon examination to be no *more* complicated than the facts of color demand. In no other theory has there been devised a simple chain of chemical events which necessitates (parallels) the three most important and striking phenomena of color. These fundamental phenomena are so universally overlooked—some by the adherents of the Hering theory and some by the adherents of the Helmholtz theory—that it will be desirable to keep them before the eye in parallel columns:

(1)

The number of "adequate," homogeneous, electro-magnetic vibration-periods (wave-lengths) is THREE.

(2)

The number of homogeneous (non-blended, or unitary) color-sensations is FIVE.

(3)

But the five distinct color-sensations are *not* independent variables, they are subject to the conditions:

$R+G=Y$

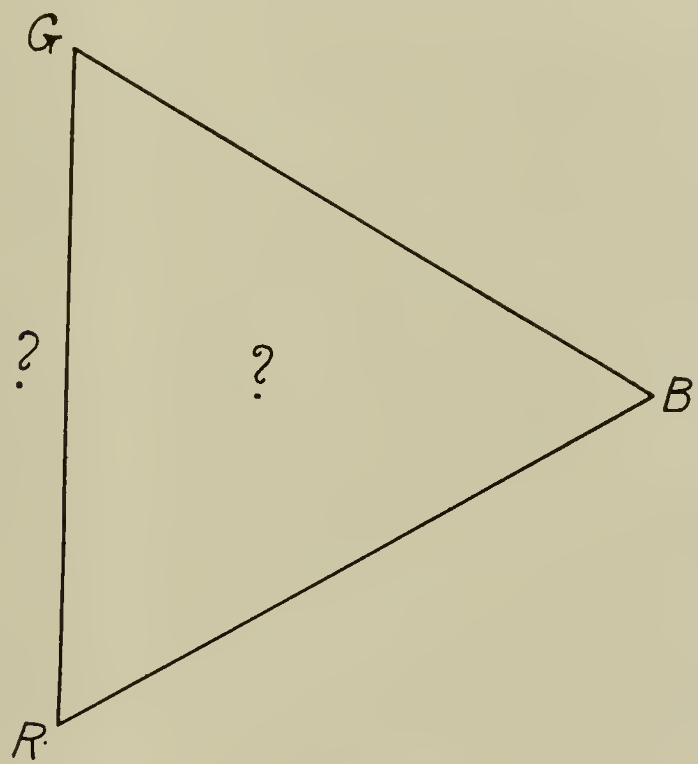
$Y+B=W$

(and hence

$R+G+B=W$).

The statement in column (3) amounts to saying that neither red and green, nor yellow and blue, ever occur in consciousness together: they are disappearing, or vanishing, or mutually extinguishing, color-pairs: in place of them appear (for red and green) yellow, and (for yellow and blue) white. We have here, then, the whole situation in regard to color theories in a nut shell:

The Helmholtz theory is built up upon the phenomena (1), and is inconsistent with the phenomena (2) and (3). The Hering theory is built up upon the phenomena (2), explains, in a fashion,



Color Triangle.

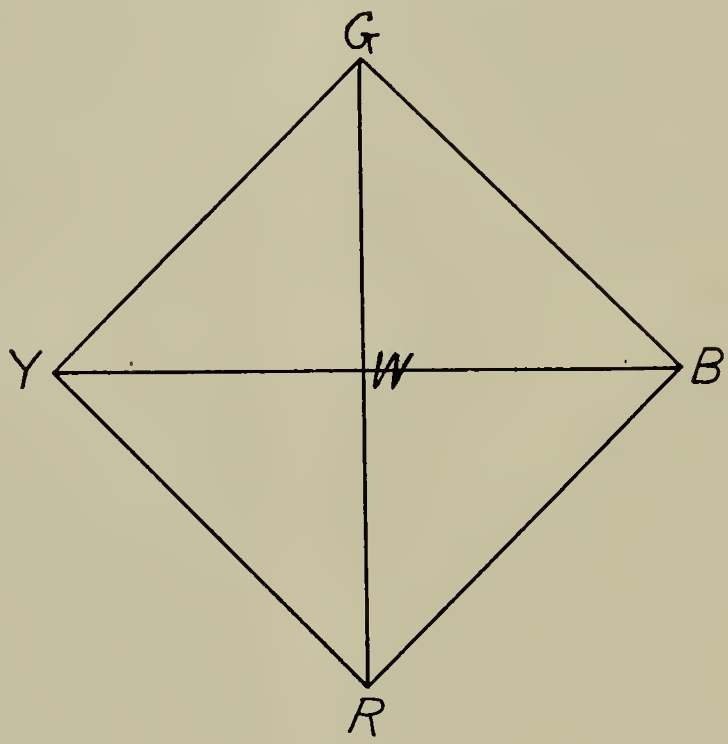
The three electro-magnetic vibrations (wave lengths) *color-triangle*, which ignores (denies) the five-foldness of the actual color-system. The blue-greens and the red-blues are well accounted for, but we never experience, in fact, any red-greens, nor any red-green-blues.

one part of phenomena (3)—namely, that Y+B=W, but garbles the other part, affirms that R+G=W, when in reality R+G=Y. It is thus wholly inconsistent with (1), and with part of (3).

There is evident necessity for a hypothesis which will take account of all of these seemingly inconsistent phenomena at once. The development hypothesis of color is an hypothesis (1) in which the adequate electro-magnetic stimulations of the chemoreceptors of the retina are *three;* (2) in which the distinct, unitary, color-sensations are *five;* and (3) in which red and green are *yellow*-constitutive, while yellow

and blue are *white*-constitutive. It is surely worth while to make reasonable *all* these color-phenomena, instead of being forced to *deny* part of them, as is done in both the Hering and the Helmholtz theories.

Symbolic of the Helmholtz and the Hering theories respectively, are the color-triangle and the color-square:



Color Square.

The five-sensations (psychological) *color-square*, ignoring (denying) the facts that three *physical* components are sufficient to produce all the color-sensations, including white, and that in reality *red* and *green* are not *white*-constitutive but *yellow*-constitutive.

The conditions which must be fulfilled in an adequate color-theory are then these: yellow and white must be due to *unitary* chemical nerve-exciters, and nevertheless these nerve-exciters cannot be simply independent, disconnected, chemical substances, for they must satisfy the relations:

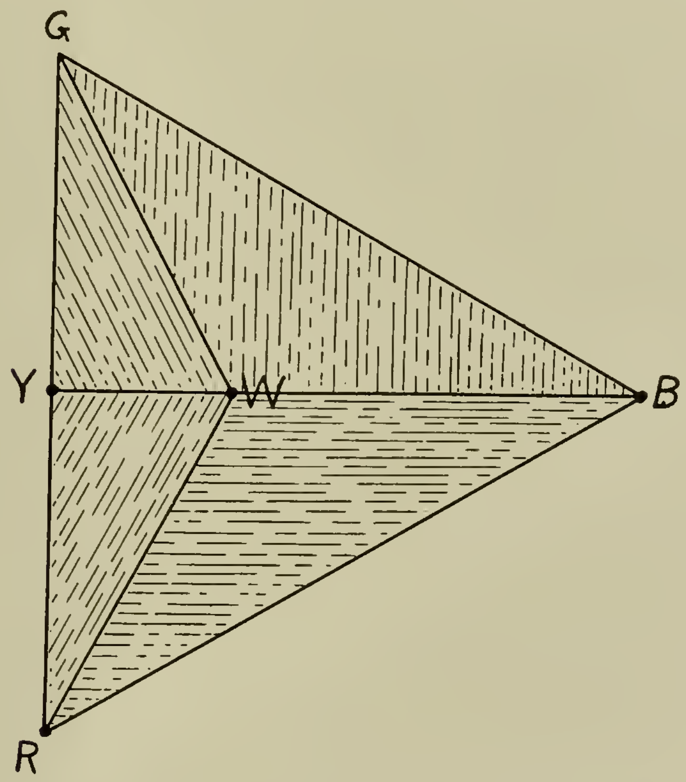
$$R+G=Y$$

$$Y+B=W$$

$$(\text{or, } R+G+B=W).$$

The adherents of both the Helmholtz and the Hering theories apparently regard these conditions as essentially inconsistent and irreconcilable: they get over the difficulties involved by ignoring (denying) the facts (*different* facts in the two cases). But they are not really irreconcilable—we have not, in fact, what the mathematician

calls "too great a number of conditions." Why not, out of the vast number of chemical processes which are accessable to us in the way of analogy, choose some one which meets the requirements of the case? Apparently the requirements of the case involve (expressed diagrammatically) that the line R Y G should be *at once both straight and broken.* But the human mind cannot accept such a contradiction as this; nor is it pleased when it can only escape contradiction by denying fact; hence, it becomes necessary to devise a quite different color-diagram (and a quite different color-theory):

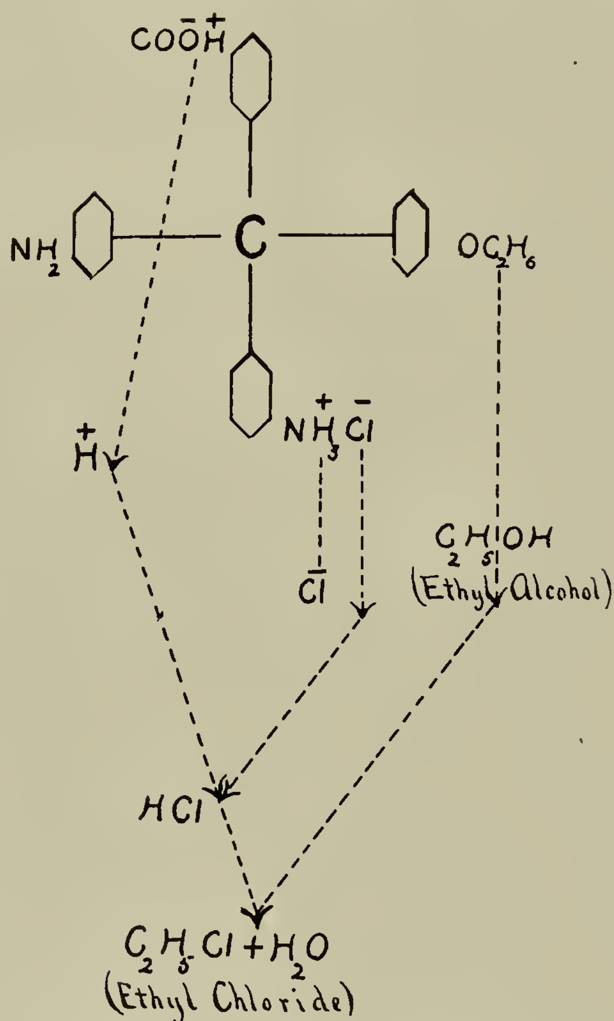


The Four-Field Color Area. With indications of the five elementary sensations.

In this color-diagram are represented at once the *threefold* nature of the physical color-stimuli, and the *fivefold* nature of the resulting psychical experiences. In the Hering color-square (Figure b) *four* distinct, different, color areas are (correctly) represented: every point within the triangle W B G will represent some one of the whitish-bluish-greens; within the area R B W will be represented the whitish-bluish-reds, etc. But there are other devices by which this fourfold character of the chromatic sensations can be represented *without sacrificing the representation at the same time of the facts of color mixture* (which can only be represented by a triangle). The different

areas may be appropriately colored: the area B G W may be made blue-green, and turning into whitish blue-green as the point W is approached. Or, the same effect can be secured by means of simple striations, of four different directions. This is what has been done in Figure *c*.

These figures (*a*, *b* and *c*) are nothing but simple diagrams, but



The Analogous Chemical Substance.

The three successive stages of a possible chemical substance corresponding to (1) a primitive achromatic form of vision (defectives, and the normal extreme periphery of the retina), (2) an intermediate, dichromatic form of vision, and (3) the normal tetrachromatic (but three-stimulus) form of vision of the fully developed individual.

they are not unimportant (if consistent theory is important), for they are complete mnemonic symbols of the essential features of the three theories which we are here discussing. They may be used to keep in mind (Figures *a* and *b*) the irreconcilableness of all theories

of the type of the Helmholtz or of the Hering kind with at least half of the fundamental phenomena of color (a different half in the two cases), and (Figure *c*) the reconciliation of the two sets of facts in the theory which *affirms* that there are five *sensations,* but also *affirms* that *three* light-rays are sufficient to reproduce them all.

The diagram will serve to keep the characters of this assumed light-sensitive substance in mind, in its three successive stages of development.

The character of this possible (and required) chemical substance is such as to account for the fact that while one side of the color-triangle exhibits the blue-greens and another side the blue-reds, on the third side, where we should expect to have the red-greens, they vanish and their place is taken by different series of sensations, the yellows. This fact is paralleled in the assumed photo-chemical substance by supposing that while the "blue" and the "green" chemical nerve-exciters remain separate substances, and each produces its regular effect (and in the same way the "blue" and the "red"), when the *red*-exciting and the *green*-exciting constituents are separated out at the same time they unite chemically, and cease to exist separately. Nothing could be simpler, chemically, than this situation: in fact, it is not difficult to find a substance which is exactly analogous to it—namely, a certain dye-stuff, rosaniline carboxylate. This is a substance such that (under proper conditions of light, heat and moisture) (1) H, Cl, and ethyl alcohol can either one of them be given off separately, but (2) when H and Cl are given off together, they unite to form the non-ionized HCl (analogue of the yellows); (3) when ethyl alcohol and *either* H or Cl are given off, they do not unite—they persist as separate substances (analogue of the blue-greens and the blue-reds); (4) when all three of these substances are given off at once they unite to form ethyl chloride (analogue of the leucogenic nerve-exciter in the retina). In other words, the ethyl alcohol set free does not unite with either the H or the Cl, until after they have first united with each other. Nothing could be more perfectly analogous to what is required for the phenomena of color-vision.† (Acree.)

Other objections to the Hering theory are these:

(1) If black and white are due to reversible chemical processes (like red and green, blue and yellow), then we ought not to be able to see black and white together,—instead of a medium grey, for instance, we ought to experience blindness,—middle-grey objects ought to drop into a cosmic whole.

(†For an exceedingly thorough-going and acute discussion of color theories from a somewhat different point of view, see Calkins', *Introduction to Psychology,* and Du Bois Reymond's *Archiv.,* 1902, p. 214.)

(2) If the quality of a certain grey is due to a certain *proportion* of black and white process, then, upon increasing, say, tenfold the *amount* of both of these constituents (keeping the proportion the same) we ought to experience a grey of the same quality, but of tenfold the intensity, just as an exact blue-blue-green can be matched in color-tone with blue-blue-greens of any number of different intensities. But this does not occur—a given *quality* of black-whiteness cannot change its intensity.

An instance of the superingenious attempts that have been made by the apologizers for the Hering theory to explain away these incongruences may be seen in Prof. G. E. Müller's supposition that there are constantly going on in the cortex both a black and a white process, equal in amount,—for no *purpose* save to keep the Hering theory in a state of suspended inanition; for other instances of like *legerdemain,* see Professor Müller's explanation of the second difficulty mentioned above (see *Phil. Rev.,* 1899, p. 89, for a discussion of this view in English), and that of Brunner, who has brought himself to believe that we never do see black and white at once, but only in rapid alternation!

But it is better to take from the beginning a theory which does not need so much explaining away.

Most theories of color (other than that of Hering) are fundamentally undermined by the fact that they fail to explain why the white sensation of the primitive rods is exactly reproduced in quality in the sensation furnished by the highly developed cones. (The views of v. Kries, Troland, Wundt, and others are rendered nugatory by this defect.) Why should there be in the rods (which are known to be structurally of low development and can therefore easily be conceived to be also chemically so) a substance whose effect as a nerve-exciter is exactly the same as that in the highly developed cones, where white light sensations are due to the combined action of "red," "green," and "blue" stimuli? What can this possibly be due to, save to a fusion of "red," "green" and "blue" factors into a chemical stimulus which is identically the same as that primitive nerve-exciter which originally occasioned white? No other situation is conceivable, in fact, as a retinal correlate to the known facts.

Color Triangle.—The facts of color mixture, as it is called, are of great importance, both for practical application and for theory. When, however, they are designated as facts of *color*-mixture, the regrettable ambiguity with which we use the term color is particularly in evidence (one of the two forms of this regrettable ambiguity). The specific light-rays of the visible spectrum are not *colored* until after

they have passed through the little photo-chemical laboratories furnished by the cones of the retina, and, on the other hand, they never strike the cortex (the structure which is immediately correlated with sensation) as periodic vibrations. What occurs is that there is a more or less definite correlation between physical light-rays of given periodicity and particular color-sensations. This correlation is definite (under ordinary circumstances) so long (but only so long) as the light-rays are homogenous: we have, for instance, these connections:

Wave-length $470\mu\mu$ *entails* or *implies* sensation red,
Wave-length $505\mu\mu$ *entails* or *implies* sensation green,
Wave-length $576\mu\mu$ *entails* or *implies* sensation yellow,
Wave-length $686\mu\mu$ to $760\mu\mu$ *entails* or *implies* sensation red.

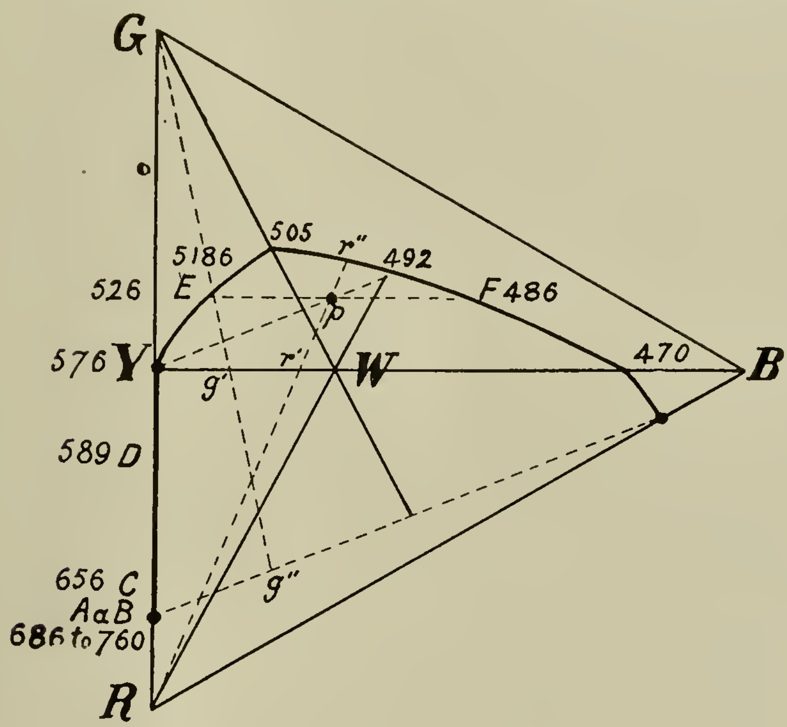
But these relations cannot be read in the opposite order—the statements are not convertible; you cannot infer, for instance, that if you experience the sensation yellow, you have before you the wave-length $576\mu\mu$. We have not here what the mathematician calls a *double* one-to-one correspondence,—the relation is a non-symmetrical or (non-reversible) one. This simple fact of psycho-physics the physicists, *inter alios,* always fail to take account of; it is invariably stated in works on physics that white *is* a mixture of all the light-rays of the visible spectrum, when what is meant is simply that the converse statement, "a mixture of all the light-rays of the visible spectrum is white" is true. There is again no such thing as "red" light, but there are erythrogenic radiations. It would be a good thing if the physicist (and everyone else) would learn to distinguish between physical light, whether made up of homogeneous or of non-homogeneous radiations, and the light (color) *sensations* which are attached to the five specific chemical nerve-exciters set free in the retina under the influence of physical light. To fix this sadly overlooked psycho-physical situation in mind, we may state it in a more striking form: We do not *see* the specific magneto-electric radiations of the visible spectrum (if we did we should surely see more than four of them); what we directly take cognizance of (or "see") is certain four chemical substances which light produces in the cones of the retina. The light-sense is a chemical sense, not a mechanical sense; the immediate retinal correlate of a fourfold chromatic sensation is a fourfold chemical nerve-excitation.

It is practically impossible to keep fully in mind the complicated facts of color mixture without the diagrammatic aid which is furnished by the color triangle. In every laboratory or lecture room where color is discussed, this diagram (Figure a) should be kept hanging on the wall, as an indispensable *aide-mémoire* to many facts. It has nothing

to do with the Helmholtz theory, though the facts which it exhibits to the eye are facts which have been obtained in the Helmholtz laboratories and by means of the complicated (and expensive) Helmholtz color-mixing apparatus (*Spektralfarbenmischapparat*, see catalogue of Spindler and Hoyer, Göttingen, p. 65), and though they are also the facts which suggested his color theory to Helmholtz. The color triangle does, of course, exhibit the fact that three light-stimuli are sufficient to reproduce all the color sensations, but that is a fact which is not incompatible with other theories besides that of Helmholtz.

The color triangle is in the first place a diagrammatic representation, in trilinear co-ordinates, of the fact that all the chromatic sensations, which are due, in the first instance, to the homogeneous lights of the spectrum, can be reproduced (save for some falling off in chromaticity in the yellow-greens) by a combination of any two of the homogeneous lights λ470 ("blue"), λ505 ("green") and λ686 ("red"), and that when all three of these physical constituents are united at once the sensation white is produced—exactly the same sensation as if the physical stimulus present were the entire gamut of wave-lengths. This remarkable fact—so very different from the situation which meets us in the sound gamut—is, of course, represented, in any theory of the chemical process involved, by supposing that there is a *limited number of constituents* in the nerve-exciting substance produced by the action of light upon the visual substances of the retina. This assumption, indeed, may be regarded rather as statement of fact than as theory; no theory which fails to incorporate it (as do those of Göller, Patten, Zenker, Wundt and others) is deserving of a moment's attention. The number of these chemical constituents must evidently be at least three. But the simplest consideration of the psychological facts involved,—of the fact, e.g., that the number of simple (unitary, non-blended) *sensations* which we experience is *five*,—viz., red, yellow, green, blue and white (leaving out of account, for the moment, black, which, though it is a *visual* sensation, is not one of the *light* sensations) shows that the constituents involved are exactly five in number. No color theory at present can be regarded as a theory at all which does not take account of the five distinct light-sensations (or of the six visual sensations, when black is included). Helmholtz made the mistake of supposing that because the combinations of these three constituents are *sufficient* to account for all the phenomena of "matching by physical mixtures," therefore the actual number of the constituents must be three, no matter what the other demands in the way of accounting for phenomena might be. His theory was pre-physiological, and pre-evolutionary as well. It no

longer needs to be taken account of as a color-theory; nevertheless the facts of light-ray mixture upon which it was built up are still of the utmost importance, and they are quite incompatible with the theory of Hering. Hering did a most needed work in restoring yellow and white to their rightful unitary character, but he introduced for that purpose conceptions which are quite unworkable.



The Detailed Color Triangle.

The color triangle constitutes a *vade-mecum*, then, for holding together for the eye a number of the color phenomena (Figure d):

(1) Complimentary colors (wave-lengths) are to be found at opposite ends of lines through the central point, W.

(2) The degree of whiteness of any color (spectral or non-spectral) corresponds to its nearness to the point W.

(3) It has been shown (König, v. Kries, Nagel) that the color-systems of the dichromatic individuals are "reduction-systems" from the vision of the normal eye,—that is, every color-matching equation which holds for the defective eye will hold for the normal eye also, but not conversely. This circumstance is represented in the color-triangle by the fact that lines through R and G go through all the points which are indiscriminable in color by these defectives (i. e., the so-called confusion colors).

(4) Any non-spectral color can be matched by an indefinite number

of combinations of wave-lengths taken, in amount, in the inverse proportion of the segments of the line joining them. (For further details, see Baldwin's *Dictionary of Philosophy and Psychology,* Article Vision.)

The same phenomena (namely, the whole collection of facts regarding color mixture, and the whole collection of facts regarding the typical cases of color-blindness—which see) are expressed in a different kind of diagram.—(C. Ladd Franklin.)

Colour. For compounds and derivatives of this word see the corresponding caption under **Color.**

Columbian spirits. A trade name for the so-called "purified" or "deodorized" wood or methyl alcohol, the most insidious and most dangerous of the many forms of methylated spirits in the market. The drinking and inhalation of this particular poison has been responsible for many deaths and blind people, especially in the United States.

An editorial in the *Journ. Am. Med. Assoc'n* for Feb. 14, 1914, treats this subject in a judicial manner and it is here quoted in its entirety.

Nearly a thousand cases of poisoning attributed to wood alcohol (mostly due to drinking it) have been reported in the literature since 1893, the date which marks the advent of methyl alcohol of a high grade of purity, like that sold under the trade names of "Columbian Spirits," "Colonial Spirits," "Manhattan Spirits," "Pro Spirit," etc. The growing publicity of these distressing facts, accentuated by the agitation which has been widely fostered in print by the *Journal* among other publications, has directed attention to the danger from wood alcohol to such a degree as to arouse considerable uneasiness in the industries connected with its manufacture. We are informed from trustworthy sources (these statistics are given on the authority of an editorial in the *Journal of Industrial Engineering and Chemistry,* 1913, v, 712) that the business involves the annual production and use of about ten million gallons of the substance with a capital investment in this country of about twelve million dollars in the industry, which employs over three thousand working people. It is interesting, therefore, to note the attitude taken in quarters in which business interests must inevitably permeate the purely humanitarian features that are also concerned. We are reminded that since man began to handle fire he has been utilizing dangerous substances to his own good purposes. It is, of course, true that many of the most useful substances are dangerous and poisonous. Deadly cyanids are used for extracting gold; poisonous strychnin is employed as a heart stimulant; toxic phenol finds wide application as a disinfectant, and corrosive acids are used in multitudinous operations.

Despite this indisputable statement, we cannot overlook the equally cogent fact that there are in all the cases mentioned inherent factors which of themselves limit the probability of harmful results in the uses of these poisons. Either there is an adequate understanding of the great dangers involved, or the applications are as a rule in the hands of experts who may be trusted to prevent untoward results. It is contended that methyl alcohol is used extensively as a valuable solvent and in the manufacture of many important materials, and that its legitimate use should not be prohibited. We may agree with these contentions and still raise the question whether or not in the case of the particular poison under discussion, methyl alcohol or wood spirits, the existing legislation is adequate to prevent those disasters which experience has already demonstrated to occur.

It has been noted that wood alcohol presents a unique case for legislation, not only because of its general resemblance to ethyl alcohol, but especially on account of the word "alcohol," which has a definite meaning to the chemist, but is rather associated in the lay mind with "drink." The dangers, however, are by no means limited to the possibility of introducing methyl alcohol in foods or drinks. When, in 1906, the general agitation for a tax-free, denatured ethyl alcohol brought about hearings before the committees of Congress, the injurious action of wood alcohol on the general health and the eyesight of working people handling it in the industries was strongly emphasized by manufacturers employing it, workmen and experts. In the light of this it is interesting to learn the conclusions and recommendations of an unbiased report primarily arrived at from the point of view of the chemist and the industries rather than the alleged one-sided position of the hygienist. This is now available in the pamphlet on wood alcohol prepared for the New York State Factory Investigating Commission by Charles Baskerville, chairman of the Committee on Occupational Diseases of the American Chemical Society. (Baskerville, Charles: *Wood Alcohol: A Report on the Chemistry, Technology and Pharmacology of and the Legislation Pertaining to Methyl Alcohol.* This can be secured by writing to the Commissioner of Labor, Albany, N. Y. An abstract appears in the *Journal of Industrial Engineering and Chemistry*, 1913, v, 768.) The report does not attempt to pass final judgment on the once debated question which has already been discussed in the *Journal* (Methyl Alcohol as a Poison, editorial, the *Journal A. M. A.*, Nov. 30, 1912, p. 1974), namely, whether the morbid action of wood alcohol is due to the concomitant impurities or not. Economic reasons prohibit the extended use of chemically pure methyl alcohol in the arts and manufacturing industries, although the purest

material is now used in certain products. The abuses of methyl alcohol prior to the more recent activity in the direction of pure foods and drugs must be admitted, and likewise the undoubted toxicity of the methyl alcohol of commerce.

There are at present sixty-three manufacturers of wood alcohol in the United States. In their plants the workmen are liable to come into contact with the vapor—one of the modes of intoxication—only in neutralizing the acetic liquor with lime and in filling the shipper containers. Baskerville maintains that general requirements for ample ventilation should meet these difficulties which, in fact, do not now exist in the works inspected in New York State. In the industries in which wood alcohol is employed it often serves as a solvent. Here it can exert deleterious action if the workmen (1) inhale the vapor; (2) dip their hands and arms into the liquor, or (3) drink it. Ample ventilation will avert the first danger; impervious gloves will prevent the second; only education can ward off the third. The precautionary measures are summarized in the New York report in the following recommendation as to laws which should be enacted if not already on the statute books: 1. To prohibit the presence of wood alcohol in any form of material intended for internal use. 2. To prohibit the presence of wood alcohol in preparations intended for external use on the human body. 3. To require ample ventilation in works in which wood alcohol is made or used in manufacturing products wherein the wood alcohol remains as such; the same law should apply where the products containing wood alcohol are used up, as for example, in varnishing vats in breweries. 4. To require containers in which wood alcohol is marketed to bear suitable display labels of warning.

After all is said, the fact remains that the manufacture and sale of Columbian spirits and other forms of so-called "deodorized" methyl alcohol is a menace to the health of the people and ought to be suppressed. *There is no valid argument for permitting its manufacture so long as an effective and cheap substitute exists.*

The Committee for the Prevention of Blindness of the State of New York, in an effort to prevent the ill effects attending the use of Columbian spirits, has issued (1913) an illustrated circular giving a short account of the damage done by this poison. A portion of this circular is here reproduced and every ophthalmologist is asked to use his influence to prevent the illegal employment of this deadly form of wood alcohol; it is even a question whether the manufacture of so lethal a compound, frankly intended to take the place of the comparatively harmless grain alcohol—on the score of cheapness—should not be *prohibited by legal enactment.*

Wood alcohol is a poison. A teaspoonful may cause total blindness, a larger quantity often causes death.

Twelve persons were blinded and three were killed by wood alcohol during 1912 in New York City alone.

Only within recent years has wood alcohol become so dangerous to life and sight. Formerly it was a dark, bad-smelling, bad-tasting fluid which no one was tempted to drink. A process is now known by means of which this color, taste and odor are removed.

Wood alcohol, when purified in this way, looks, tastes and smells like "good" (grain) alcohol, and may easily be substituted for it in white whiskey, cordials, brandy, essences, extracts, patent medicines, etc.

Wood alcohol is poison and should not be used in any drink or medicine.

As much blindness and death have been caused by breathing the fumes of wood alcohol as by swallowing the liquid.

These fumes come from wood alcohol used in various trades—for example, in varnishing furniture, lead-pencils and the inside of vats; in dyes for coloring feathers and artificial flowers; in shellac, for stiffening hats; in the manufacture of photo-engravings; and from stoves and lamps in which wood alcohol is burned.

Many men are blinded and others killed by fumes inhaled from wood-alcohol varnish used to varnish the inside of vats, when the only means of ventilation is the small manhole. The workman should be protected against poisoning by a tube and ventilator through which sufficient fresh air is supplied.

Because most people do not know that the liquid and its fumes are dangerous to life and sight.

Because wood alcohol is used in various trades and without precautions to protect workmen.

Because wood alcohol is sold by druggists, without a poison label as required by law, under various trade names, such as *Columbian Spirits, Eagle Spirits, Lion d'or, Colonial Spirits, Hastings Spirits, Acetone Alcohol,* etc.

Because wood alcohol is sold in groceries and paint shops in unlabeled or wrongly labeled bottles and cans.

Because unscrupulous liquor dealers refill whiskey bottles with cheap drinks adulterated with wood alcohol, and sell them to ignorant customers.

Because purified wood alcohol is sold for the home preparation of cordials, etc.

Use "industrial" ("denatured") alcohol *instead of wood alcohol,* particularly in the trades. It is *cheaper* and absolutely *safe.*

Industrial alcohol is grain or "good" alcohol rendered unfit for drinking. It contains ninety parts of grain alcohol, ten parts of wood alcohol and one-half of one part of benzine or pyridine. There is too little wood alcohol present to give off dangerous fumes.

Use only "grain" alcohol in the home preparation of cordials, etc. Ask your Senator and member of Assembly to support legislation—(1) Prohibiting the sale of wood alcohol under any trade name or in any mixture without being labeled poison. (2) Prohibiting the use of any kind of wood alcohol in any article of food or drink, or in any mixture intended for internal use. (3) Requiring adequate ventilation in shops and workrooms where wood alcohol is manufactured or used; also ventilators for vats or other large containers which are varnished inside with any kind of wood alcohol varnish. Workmen should spend every alternate half hour in the open air when working under such conditions. See **Alcohol, Methyl**; also **Methyl alcohol**; and **Toxic amblyopia.**

Colutea vesicaria. (L.) A plant indigenous to the Cape of Good Hope, and used in "ophthalmia."

Colybia. The ingestion of various Japanese mushrooms has been reported as causing eye symptoms. Inoko (*Fortschritte der Medicin*, 1893, Vol. 2, p. 444) describes these, and from his report we gather the impression that a number of the poisonous fungi mentioned resemble our *amanita.* In every instance they produced, as a part of the intoxication, marked dilatation of the pupil, amblyopia, and cloudiness of the visual field. In several instances these symptoms were followed by violet-vision and hallucinations of sight.

Coma. Coma aberration. The hazy border which surrounds an object which is viewed through an imperfect lens. See **Aberration.**

Coma, Eye symptoms in. As Weeks (*Diseases of the Eye,* p. 759) points out, in all conditions of coma the eye symptoms and signs may give valuable information. If due to organic brain disease there may be deviation of the eyes, choked disk, dilated pupils; if the intracranial pressure is increased, dilated pupils and clonic conjugate deviation. If from cerebral hemorrhage, miosis, inequality of pupils, conjugate deviation are present; if from uremia, albuminuric retinitis. Narcotic poisoning occasions extreme equal miosis. When due to atropine or hyoscyamine, the pupils are widely dilated.

Combination-back. The lens-system of a microscope in which the objective farthest from the object is composed of a plano-concave lens of flint glass and a bi-concave lens of crown glass. It may also be made of a bi-concave and two bi-convex glasses.

Combination-front. The lens-system of a microscope nearest the objective.

Combined excision. This expression is generally used to indicate Kuhnt's operation of extirpation of the tarsus, with removal of the trachomatous conjunctiva covering it. See **Trachoma.**

Combined operation in cataract. For several generations the question whether it is better, as a rule, to excise a portion of the iris as a part of the cataract operation has been asked and variously answered. It would require many pages to discuss the merits and defects of the two principal methods of extracting senile cataract. Probably the proper form of inquiry should relate not so much to a decision as to which is the better method, but to an attempt to decide the cases in which one operation ought to be performed in preference to the other. In other words, a selection of cases is called for because it is undoubtedly true that one operator may employ the simple method too much. See **Cataract, Senile.**

Combined sclerotomy. This operation was devised (for the relief of glaucoma) in 1894 by de Wecker (*Annales d'Ocul.*, 1894, p. 261). See **Sclerotomy, Combined.**

Combiner, Galvano-faradaic. An electrotherapeutic instrument so arranged that the galvanic and faradic currents can be used alternately or in combination.

Comedo. Grubs. Grub-worms. Black-heads. A chronic disorder of the sebaceous glands characterized by yellowish or whitish pin-point and pin-head-sized elevations, containing in their centre exposed blackish points. They are found usually on the face, back of the neck, chest, and back, and are often associated with acne. They occur as a rule in the young. Occasionally a parasite, the *Demodex folliculorum* (q. v.), a small mite, is found in each comedo.—(Gould.)

Comédon. (F.) Comedo.

Côme, Frere. A celebrated eighteenth century lithotomist and oculist. See **Baseilhac, Jean.**

Comes obliqui superioris. (L.) An anomalous, accessory, superior oblique muscle of the eye, resulting from the separation of the muscle into two parts.

Cometenpupille. (G.) n. Literally, "comet-pupil"; a name first employed by Helling to describe those forms of the pupil seen in coloboma of the iris.

Cometocora. (L.), f. n. The comet-shaped pupil of coloboma iridis.

Comet pupil. A term proposed by Helling, for coloboma of the iris. The term never came into very general use. "Coloboma iridis" was invented by von Walther, who was also the first to attribute the

deformity in question to an arrest of development instead of to a wound received *in utero.*—(T. H. S.)

Comitant squint. Concomitant squint. Concomitant strabismus. In comitant or concomitant squint—as the adjective implies—the non-fixing eye generally follows or accompanies all the movements or excursions of the fellow organ. In other deviations—paralytic squint for example—there is a limitation of these excursions, so that the deflected eye does not necessarily accompany the ocular movements of the other eye. See **Muscles, Ocular.**

Comitant strabismus. See **Comitant squint.**

Commagenum. A salve which, in ancient Greco-Roman days, enjoyed an especial reputation as an ocular pain reliever. To produce this valuable article, goose grease was mixed with cinnamon, cassia, white pepper, and *valeriana scabiosæ folia* in a vessel chilled with snow.—(T. H. S.)

Commissura oculi externus. (L.) External canthus. See **Canthus.**

Commissura oculi interna. (L.) Internal canthus.

Commissura oculi minor. (L.) External ocular canthus.

Commissura oculi nasalis. (L.) A synonym for internal canthus.

Commissura oculi temporalis. (L.) Another name for the external canthus.

Commissura palpebrarum externa. (L.) A synonym of external canthus.

Commissura palpebrarum interna. (L.) Internal angle or canthus.

Commissura palpebrarum lateralis. (L.) A synonym for external canthus.

Commissura palpebrarum medialis. (L.) Internal ocular angle, or canthus.

Commissur der Augenlider. (G.) An angle or canthus of the eyelids.

Commissur der Sehnervenganglien. (G.) The posterior (optic) cerebral commissure.

Commissure of the chorioid. The ciliary ligament.

Commissure of the eyelids. The external or internal canthus or angle of the eyelids. See **Canthus.**

Commissure, Optic. The chiasma or optic commissure is an important portion of the intracranial optic nervous system and is formed by a decussation of the two optic tracts in front of the *tuber cinereum.* The decussation is complete in many animals, but in man some of the fibres of each tract do not cross over and are not continuous with the opposite optic nerve; they either enter the opposite tract or pass along and are continuous with the nerve fibres of the same side. See **Chiasma.**

Common salt. See **Sodium chloride.**

Commotio cerebri. (L.) Concussion of the brain (q. v.).

Commotion de l'oeil. (F.) COMMOTIO RETINÆ. Concussion of the retina, or amotio retinæ.

Commotio retinæ. TRAUMATIC RETINITIS. CONCUSSION OF THE RETINA. EDEMATOUS SWELLING OF THE RETINA. BERLIN'S OPACITY. BERLIN'S EDEMA. Concussion or paralysis of the retina from severe falls or blows upon the eye or head, first described by Hirschberg in 1875, is characterized by sudden and complete blindness, but with few or no ophthalmoscopic changes, and vision is often perfectly restored.

Blows on the eye may be followed by edematous swelling and opacity of the retina, the change being situated generally in a part of the retina opposite to the point of impact. There is marked contraction of the pupil, which dilates imperfectly to atropin. There is some episcleral injection and reduction in the acuity of vision. The tension is normal, as a rule. Stephenson, however, has reported a case of concussion of the retina with minus tension. Ophthalmoscopic examination made an hour or two after the injury will show a grayish-white or milky-white cloudiness existing in disseminated spots and not involving the blood-vessels. Soon the spots may coalesce and the whole fundus may be involved. In from twenty-four to thirty-six hours the process is fully developed. Then it begins to decline, the fundus-reflex again becomes visible, and in a few days the eye is of normal appearance. In rare instances a system of fine radiating lines will be found around the yellow spot. The retina is not thrown into folds, and this fact serves to differentiate commotio retinæ from retinal detachment. The prognosis is favorable. There may be coincident retinal hemorrhages, spasm of the ciliary muscle, and transient astigmatism. The treatment will include rest, the use of atropin drops, and the wearing of smoked glasses.—(J. M. B.)

According to Parsons (*Pathology of the Eye,* Vol. 4, p. 1160), Haab gives the following statistics: In 167 cases of contusion of the eye in which ophthalmoscopic examination was possible, 82.6 per cent. showed no changes, 12.5 per cent. edema of retina and macula, 4.7 per cent. edema of macula only. Of the 12.5 per cent. sixteen cases cleared up entirely, with normal or nearly normal vision. In five cases pigmentation of the macula followed, visible 1, 3, 4, 8, and 19 days respectively after the injury. The prognosis in these cases is much worse, the best vision being 6/60, and in one case optic atrophy, in another choroidal changes, ensued. Lawford describes extensive retinal pigmentation and choroidal atrophy. Berlin attributed the edema to extravasation of blood between the choroid and sclerotic, such as he observed in

rabbits. This view is untenable on the grounds that blood is never extravasated between the retina and choroid in these cases, as might be expected at least as an occasional event, and retinal edema does not accompany choroidal rupture; moreover, the rapid recovery is against the presence of a hemorrhage. Hirschberg considered it probable that the blow caused local reflex vaso-constriction, leading to transitory blindness, followed by increased permeability of the vessels, resulting in edema. Berlin's experiments support the view of a temporary anemia. Makrocki invokes molecular changes in the nerve-fibres as a result of the anemia. Ostwalt and Haab state that the retinal vessels participate in the anemia. Vaso-constriction of pathological origin in other parts of the body is followed by vaso-dilatation, which increases the tendency to transudation, and this is likely to be very marked in the macular region, where the chorio-capillary network is specially fine. Denig's experiments on animals support on the whole Berlin's findings, and his conclusions have in turn been confirmed by Bäck. Denig considered that the vitreous was forced against the retina, leading to separation of the expanded ends of Müller's fibres, rupture of the internal limiting membrane, fluid being squeezed into the nerve-fibre layer. Paralysis of the retinal and choroidal vessels caused transudation, the fluid in the latter instance being situated between the rods and cones. In the more severe cases active dislocation of the structures in the layers of the retina is probable. Tepljaschin found the maximum accumulation of fluid in the inner nuclear layer. That the essential cause of the edema lies in the condition of the vessels is shown by Wagemmann's experiments and by the macular edema which occurs in cases of division of the optic nerve anterior to the site of entry of the central vessels. Further, there are other cases of commotio retinæ without direct injury to the globe, which must be explained on similar grounds. See, also, **Berlin's opacity.**

Commotio spinalis. The so-called "railway spine," in which without much or any evidence of organic lesion, pareses and other symptoms—sometimes ocular symptoms—persist for a long time, or may be permanent. Some cases are undoubtedly instances of traumatic hysteria; others resemble, pathologically, cerebral concussion, and in still other examples the pathology is obscure.

Commozione della retina. (It.) Retinal concussion.

Comocladia dentata. It is said that in the West Indies flies may carry the irritating pollen of this plant and introduce it into the eyes of people during sleep. As a result an acute inflammation is set up, with the formation of blisters on the eyeball.

Comparative anatomy of the eye. See **Comparative ophthalmology.**

Comparative ophthalmology. COMPARATIVE ORGANOLOGY OF THE EYE. The visual organ, as it appears in the numerous and infinitely varied forms of animal life, may be studied in its relation to the various sub-kingdoms, classes and orders; or its component parts, as they are found throughout the animal kingdom, may form special subjects of investigation; in other words, one may investigate the purely *human* side of this subject, *i. e., comparative ophthalmology,* or the investigator may study the *comparative organology* of the visual apparatus in all animals, Man included, without especial reference to Man. Doubtless the student who wishes to gain a thorough knowledge of this important subject should engage in both kinds of study. He ought to follow, for example, the account given by Kalt, Motais and others in the *Encyclopédie française d'Ophtalmologie,* Vol. 2, pp. 611 to 942, where the ocular apparatus, as a whole, is described in its relations to the various sub-kingdoms, classes, orders, and families, at the same time considering the various component organs in *their* relations to the divisions and sub-divisions just indicated.

To this study one might well add such works as C. Hesse's *Vergleichende Physiologie des Gesichtssinnes,* 1912; Victor Franz's *Sehorgan,* being the ophthalmic portion of Oppel's *Lehrbuch der Vergleichende Mikroskopischen Anatomie,* 1913; the chapter by Pütter (*Organologie des Auges*) in the third edition of the Graefe-Saemisch-Hess *Handbuch der gesamten Augenheilkunde,* 1913; and Otto Zietschmann's chapter in Ellenberger's *Handbuch der vergleichenden Mikroskopischen Anatomie der Haustiere,* 1906. The writer is greatly indebted to these authors for much of the information in this section, written to introduce the student to the fundamentals of comparative ophthalmology.

Some knowledge of general zoology is, of course, presupposed in a serious student of comparative ophthalmology. If this be lacking it may to some extent be supplied by a diligent perusal of such works as Herrick's *Text-Book in General Zoology* and Colton's *Zoology, Descriptive and Practical.* To this research should be added, if it be at all posible, one or two practical courses in a properly equipped laboratory with, for instance, Parker and Haswell's *Text-Book of Zoology* as a constant companion.

Introductory to the present section and as references for those readers whose zoological opportunities have been so small as to require them, a short account of animal life is given. A portion of it, as well as the animal classification and general zoological notes, are quoted from the London Science Class-Books (extremely simple and

elementary primers) on *Invertebrata* and *Vertebrata* by Alex. McAlister.

Every species of animal is limited to a definite geographical area. Thus the earth's surface may be divided into regions, each characterized by special inhabitants, and the collected animals of any region we speak of as its *fauna.* As a rule, life increases in amount in any country with increasing, and diminishes with diminishing temperature. Thus the fauna of a tropical exceeds that of a temperate region. The number of animals is also larger when the difference between the winter and summer temperature is small, than in a country with the same mean temperature but with a greater range between maximum and minimum. Moisture is also favorable to animal life, and the fauna of a moist exceeds that of a dry region, other things being equal.

Many animals live in places from which light is excluded, as in caves; *these have rudimental eyes,* and are white or colorless. Many large caves, like those of Kentucky, Adelsberg, etc., have thus peculiar blind inhabitants.

Sometimes the presence of one animal prevents the diffusion of others; thus in Africa the tzetze fly renders whole tracts uninhabitable by oxen and horses, which are destroyed by its poisonous bites.

The fauna of a limited area of a continent usually exceeds that of an island of equal size in its number of specific forms; and the fauna of an island lying near a continent generally resembles that of its neighboring continent. Oceanic islands or those isolated by very deep straits have often remarkable faunæ of their own, e. g., the Galapagos and New Zealand.

Tropical species are, as a rule, more limited in range than are those of temperate climates, and simpler animals are usually more widely distributed than are the more complex.

Fresh-water inhabitants are the fewest specifically, and as a rule are simpler in organization than allied forms inhabiting the sea. The fourth sub-kingdom (echinoderms) has no fresh-water representatives; the second (pariferia) has only three, and the third (vermes) only six species living in this medium; while the others are not very numerously represented in fresh water.

The *sea is the home of nine-tenths of the invertebrates* (*if we exclude insects*), and there are also definite ranges of extension to be noticed in the cases of marine species. The conditions limiting specific life in the sea are depth, currents, and temperature.

Terrestrial animals are the most specialized, and have organs in a more concentrated condition than in their aquatic allies.

Some animals pass their lives within or on the bodies of others

(*parasites*), and this condition induces striking alterations in structure. Some of these intruders collect their food independently of their host; of this nature are the sponges, which live rooted on crabs, or the barnacles on the skin of the whale. The second series of intruders are fellow commoners with their hosts, feeding on the food which their entertainer collects; these are called *symbiotics*. In a third class the parasite is a pensioner on the body of his host, feeding on his substance. Such forms are *true parasites*.

In all these conditions there is a diminished necessity for locomotion and for food-capture on the part of the parasite; so the organs of motion, of sense, and of nutrition retrograde, but as the parasitic condition involves difficulties in the continuance of the species, the organs of multiplication are enormously increased in size and complexity.

Animal classification. The vast number are classified somewhat differently by various authorities. The following nomenclature, used in the London Science Class Book, is as practical as any. McAlister says that those individuals which are so far identical in structure as to lead us to believe that they are descended from common parents we speak of as belonging to the one species. *Species* is thus our unit in systematic zoology, but as two individuals are seldom absolutely identical in all respects specific distinctions must be more or less arbitrary. A group of allied species embodying the same structural ideas is called a *genus*. An assemblage of allied genera is a *family;* a group of related families make up an *order;* while related orders make up a *class,* and the several classes included in the animal kingdom are united in certain primary categories called *sub-kingdoms*. Systematic zoologists give a Latin name to each of these, and for convenience each species is designated by a Latin word to which is prefixed the name of the genus. The specific name is generally an adjective, the generic is a substantive, and should be written with a capital letter. Thus the dog is called by zoologists *Canis familiaris,* Canis being the generic, familiaris the specific namé. *Canis aureus* is the jackal, *Canis lupus* the wolf. That species in a genus which most strikingly embodies the generic characters is the type of the genus. We also speak of the type of a family, of an order, or of a class, the type being that species which displays most clearly the characters of the group; and for convenience we attribute certain characters to ideal types to illustrate truths in classification. The type genus usually gives its name to the family; thus the dog-family is called *Canidæ*.

The *animal kingdom* includes eight sub-kingdoms. In these may be observed a certain progressive increase in complexity, from one end of

the series to the other; but they do not make a linear series, as the highest organism of each is in no degree related to the lowest organism of the next sub-kingdom, being usually much more advanced and specialized, so that in point of complexity the sub-kingdoms overlap each other.

EYES OF INVERTEBRATES

Sub-kingdom 1. *Protozoa;* the simplest animals, which have neither body-cavity nor nervous system, and thereby differ from the other sub-kingdoms, which possess at some time in their life-history a body-cavity, and which are collectively called *Metazoa.*

Protozoa include such animalcules as the rhizopods, simple animals with false feet; *amebæ;* the parasitic *sporozoa; radiolaria,* minute animals from the sea bottoms enclosed in flinty shells; and the *infusoria,* microscopic, generally ciliated animalculæ.

Sub-kingdom 2. *Porifera;* sponges, which have an internal cavity with one outlet and many inlets, bounded by a bilaminar wall.

Sub-kingdom 3. *Cœlenterata;* jelly-fishes and sea anemones, having a stomach cavity and a body cavity as an outgrowth therefrom, and a radiate symmetry. The mouth, bordered by tentacles, is armed with thread cells.

This division includes hydras; medusoids, the "Portugese man of war"; siphon-bearers (*Siphonophora*); disc-bearing jelly-fishes (*Rhizostoma* and *Chrysaora*); *Ctenophora* or rowers; the *Actinozoa* or sea anemones that look like living flowers, certain forms of which form the coral reefs of tropical seas, to which also the *Alcyonaria* or "dead men's fingers" belongs.

Sub-kingdom 4. *Echinodermata;* star-fishes and sea-urchins, also radiated, with a body-cavity separate from the stomach, a nervous system and a system of water-tubes which are agents in locomotion.

Echinodermata include sea urchins, sea hedge-hogs, star-fish, sea cucumbers and other forms. Several of these humble but ravenous scavengers of the ocean possess "eyes," though most species exhibit the simpler "eye spots" and ocular plates instead of the more complex organs seen in some of the medusæ. The sea urchin has "eyes" in the terminals of his arms that are continually held in front of the animal. In addition, each tentacle has at its base a reddish spot directed towards the mouth. This minute spot is seen on magnification to be composed of a great number of cup-shaped depressions connected with nerve-fibres.

These spiny or "hedge-hog" animals include the Crinoids or lily-like shapes, with free-swimming larvæ and fixed, adult, stellar forms; the Asteroids or true star-fishes; the Echinodea (sea urchins) and the

Holothuridea (sea cucumbers), one species of which is edible, and others harbor parasites.

Sub-kingdom 5. *Vermes;* worms which are bilaterally symmetrical, and composed of successive similar segments, with no jointed limbs, and with a water-vascular system which has no locomotory function. This sub-kingdom includes *Turbellaria* (simplest round worms); *Cestodea* or the sucker-bearing parasitic tape-worms; *Trematoda,* or flukes, another order of parasitic worms somewhat resembling the Turbellaria; the parasite *Nematelmia* (round or thread worms); *Acanthocephala* or "thorn-headed" parasitic worms; minute, non-parasitic, free-moving animalcules with circles of vibrating cilia around their extremities, hence their name *Rotatoria;* spoon or squint worms (Gephyrea); *Hirudinea* or leeches; *Chætopoda,* bristle-footed worms that resemble leeches, but are not parasites and include earth-worms and the more bristly "sea-mouse" and "lug-bait"; *Bryozoa* or moss polyps; *Tunicata* or sea squirts; *Brachiopods,* molluscoid worms enclosed in a bivalve shell.

Sub-kingdom 6. *Mollusca;* oysters, whelks, snails, cuttle-fishes, etc., possessing soft bodies enveloped in a leathery mantle, no jointed limbs, a circulatory system, often an external shell and an asymmetrical nervous system.

Molluscs include *Lamellibranchiata;* oysters, scallops, mussels, clams, cockles, and other bivalves, and *Cephalophora,* snails, whelks and limpets. In the snail the eyes are borne at the ends of the longest pair of horns and can be seen as bright black spots. In other molluscs they are stalked or placed at the bases of the tentacles. The head-bearing molluscs are divided into *Scaphopoda* (elephant's-tooth shell); *Pteropoda* (wing-like feet); *Gasteropoda* (stomach crawlers); *Cephalopods;* including the nautilus, cuttle-fish (octopus) and the squid, with their large complex eyes and the "mouth in the middle of the foot."

Sub-kingdom 7. *Arthropoda* (jointed feet); crabs, lobsters, spiders, centipedes and some insects. They have bodies made up of successive segments, with a symmetrical nervous system, an external skeleton, chitinous or calcified, and jointed limbs. Cilia are never present.

Arthropods are divided into CRUSTACEANS, that breathe through gills, as crabs, lobsters, shrimps and "water fleas," with remarkable stalked eyes (*Podophthalmia*); Arachnoids, spiders, mites, and scorpions, with their multiple eyes; Myriapods, centipedes (*Chilopoda*), gally-worms, and millipedes (*Chilognatha*); INSECTS (with their wonderful multiple eyes of various sorts) that may be divided into 13 orders; *Rhyncota*—bugs, lice, aphidæ; *Thysanura,* "fringe tails"—

sugar-lice and spring-tails; *Euplexoptera,* earwig; *Thysanoptera,* fringe-winged insects; *Orthoptera,* straight-winged insects, ants, dragon-flies, locusts, grasshoppers, cockroaches, and the mantis; *Neuroptera*—nerve-winged insects—scorpion-flies, snake-flies, and the ant-lion; *Trichoptera*—hairy-winged insects, caddis-flies; *Strepsiptera*—insects parasitic on bees and wasps; *Aphaniptera,* fleas; *Diptera*—two-winged insects—flies, mosquitoes, gnats, daddy-long-legs, Hessian fly; *Lepidoptera*—four-winged insects—butterflies and moths; *Coleoptera*—hard-winged insects—beetles of over 100,000 species, including the "ladybird," the bookworm, the firefly, and the Spanish fly; *Hymenoptera*—membrane-winged insects—ants, bees, wasps, gall-flies with four naked membranous wings.

Origin of a separate visual organ. There is probably a certain susceptibility to light resident in some part of all protoplasmic cells.

Ascending in the scale of animal life signs of a special ocular apparatus show themselves quite early. Pigmented cells in the protozoan *Euglena,* for instance, demonstrate that this new function of sight is beginning to be marked. Later, in multicellular animals, a simple "eye-spot" is realized by a pigmented and ectodermic infolding, the invaginated portion receiving some fibrils which extend to and become connected with the central nervous system. Such are the monocellular eyes of some molluscs—*Pectunculus, Arca,* etc. The development of nerve fibrils even at this early date suggests the latter arrangement of rods in the higher animals.

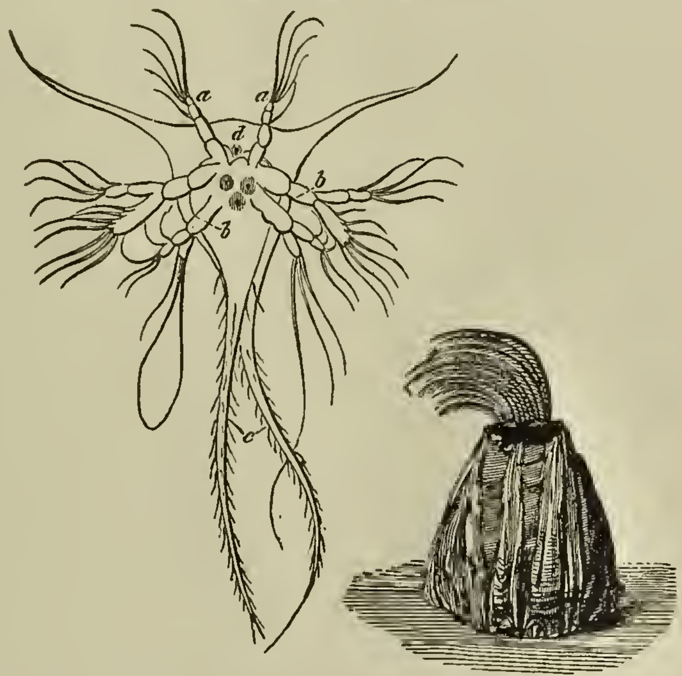
The next advance is the disposition of the pigment cells and the ectodermic tissues either as a convex or concave area, as shown in the eyes of certain molluscs and arthropods, in which luminous impressions are more definite and decided than in the eye-spots just mentioned.

The addition, later still, of a more or less perfectly formed lens or lenticular body placed within a cup-shaped depression and covered over by a transparent membrane adds much to the formation of distinct images of objects. This ocular form is reached in the vertebrates, but it occurs also (and occasionally in wonderful perfection) in some invertebrates. The eye of the (mollusc) *Cephalopods,* for instance, is constructed on this principle. Moreover, the eyes of certain worms are provided with well-shaped crystallines, not to mention a still humbler animal, the medusa *Charybdea,* whose larger, paired eyes have functionating lenses.

The second (smaller) eye-pair of *Charybdea* is less complex but still is provided with a lens placed upon a cylindrical support which is

attached to its posterior aspect. This tissue-mass surrounds the globe and extends into the wall at the back of the globe.

There are many other *Cœlenterata* not so well provided with a visual apparatus as the foregoing, but "eye spots" with more or less perfect lenses are present in most of them. In some embryos well developed ocular organs appear that have only a temporary function. As one example of this, the eyes of the free-swimming larva of the so-called "Acorn-shell" disappear in the adult form. (See the figure.)



Organs of the Larva of Balanus porcatus (Acorn-shell); *a*, Antennæ; *b*, Limbs; *d*, Eye—Compared with the adult form which has no special visual organ.

Correlation of anatomical construction and physiological purpose. As an example of this relation one may compare a human eye with that of a fish. One sees at once an entirely different refractive apparatus fitted to each. Man, surrounded by a thin, transparent medium—air—is intended to see objects fairly well in the distance. It is important that distant objects should be seen as large and distinct as possible; so he requires and possesses a dioptric apparatus arranged for distinct, distant vision. His lens must be slightly curved, widely separated from the sensitive membrane (retina) and placed in a deep (vitreous) chamber. Fish, on the other hand, living in a much less transparent medium, are mostly concerned with near objects, whose images ought also to appear large. They require (and have) a powerful refractive apparatus, with a (round) lens of short focus. The space between posterior lens surface point and the retina is, consequently, quite shallow; indeed, all short-sighted animals, concerned

only with objects close at hand, tend to have crystalline lenses approaching the piscian type.

Variations in the position of the eye. Most animals have eyes in the anterior portion of their bodies, partly as an expression of their bodily propulsive powers. Thus, many worms, as well as all the arthropods, vertebrates, and cephalopod molluses, have "eyes in their heads," while in animals that move about little or not at all the eyes are placed in different parts of their bodies. For example, both the fixed and adult *lamellibranchiate* animals display a coronet of eyes on the margin of the mantle, that soft, delicate tissue that covers the whole body of the mollusc. In some mysterious fashion they have lost the cephalic eyes they possessed in the larval state. Sabella, that lives in tubular shells, have eyes on their branchiæ; while the medusæ or jelly-fish carry them on the circumference of the body in the form of a clock.

Variety in the number of eyes. Although two is the favorite number, yet certain lizards possess a supernumerary parietal eye. Insects, including their laterally placed eyes, have a variable number of *ocelli,* some of which differ radically in function from the others. Most spiders have eight eyes; Sabella, several hundred.

Disappearance of the visual organ. When the eye becomes useless to the animal, especially if he does not require that organ either to provide himself with food or to escape from his enemies, it generally atrophies and is seen as a mere remnant. As an example, the eye of the mole is really a degenerate organ.

For a simple reason animals that live in the constant darkness of certain caves are blind, as seen in the blind fish (*Amblyopsis spelaeus*) of the Kentucky and *Proteus anguinus* of the Adelsberg caves; also in certain crustaceans that live in subterranean water-ways and under waterfalls. This subject has already been discussed under **Blind animals** and **Blind fish** in the second volume of this *Encyclopedia.* Finally, their endoparasitic life is responsible for the loss of visual organs in some worms and other animals.

VISION IN CERTAIN OTHER PARTIALLY BLIND ANIMALS.

Luminous sensations in blind animals and in those deprived of their eyes. Perception of light by the body as a whole or in part by those organisms that have no specialized visual apparatus, or in those that have been artificially deprived of it, is no uncommon phenomenon among the lower animals. *Sea anemones* are very sensitive to light, although indifferent to shadows. The anterior segment of earth worms is also affected by luminous rays. Certain sea urchins (echini), many

molluscs deprived of their visual organs, and the larvæ of many insects are at once influenced by light. Graber (1883) has seen insect larvæ provided with eyes but blind, continue to perceive variations in the illumination. Plateau (*Journ. de l'Anat. et Physiol.*, Vol. 22, 1886) noticed the same phenomenon in blind (centipedes) myriapods. The blind (cave) Proteus is still conscious of luminous impressions. Even oysters are very sensitive to luminous rays, as shown by Nagel (*Der Lichtsinn augenloser Tiere*, 1896), and will promptly close their shells when bright light is thrown upon them, or when it is suddenly removed. Similar experiments (with practically the same results) have been performed on various other molluscs. A snail *(Helix pomatia)*, deprived of eyes by amputating the tentacles that carry them, reacted distinctly to the influence of bright light and its removal. Other snails, under similar experiments, gave the same results.

These observations might be prolonged indefinitely; it is sufficient to add that although it is still a controverted question as to manner and the locality of general light perception there can be no doubt of the fact and that it is a function resident in the integument of many animals both blind and seeing.

Various types of eyes. The different orders of the two divisions of the animal kingdom exhibit a great diversity of color, light and form-perceiving organs. The so-called "eyes" vary from the simplicity of those simple *stigmata*, pigmented areas ("eye-spots") that require the microscope to differentiate their elements from the surrounding epithelium, to the complex ocular apparatus of birds of prey, that exhibit the highest degree and quality of sight.

Next in order of visual capacity after the eye-spot or, rather, light perception, one finds a closed vesicle, provided or not with a refracting lens, which, when present, generally fills entirely the cavity in which it is placed. One must conclude that this small lens really does functionate in a fashion something like that of the higher vertebrates, although the resulting image is by no means well defined.

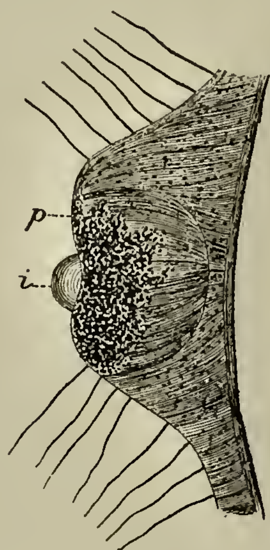
In the case of the snail, many of these lenticular bodies are in immediate contact with the surrounding (retinal) membrane and the refractive effect cannot amount to much. At the same time the degree of luminosity and the source of light may be determined in the animal by the aid of such a refractive body.

Protozoa. Both Pouchet (*Société Biolog.*, 1884) and Engelmann (*Pflüger's Archiv f. d. ges. Physiologie*) have shown even the one-celled amebæ are sensitive to differences between light and darkness. The latter observer experimented with diatoms and showed conclusively that their movements are accelerated or retarded according to

the amount of light admitted to them. The infusiarian, *Euglena*, sought the light, especially blue light.

The *Bacterium photometricum* becomes active only under the influence of light and—as its name indicates—these movements are to a degree indicative of the amount and character of the illumination.

Cœlenterata. Hydras and medusas (jelly-fishes). Trembley over a century ago demonstrated that our fresh water hydras are affected by light, although they have no special ocular apparatus. The genus *Paractis* of the sea anemones continued to remain closed as long as bright light was thrown on it, but opened out when it was in the shade. In the hydromedusas or "sea-firs" certain marginal corpuscles

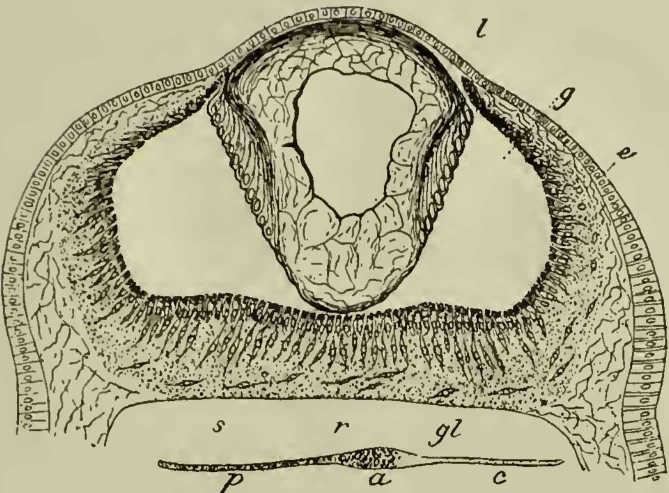


Eye of Lizzia kœllikeri. (Hertwig and Jourdan.)
i, Crystalline lens; *p*, pigmentary tunic. Retinal rods are also shown in this figure.

at the base of the tentacles are thought to be "eyes." They occur more frequently on the external surface.

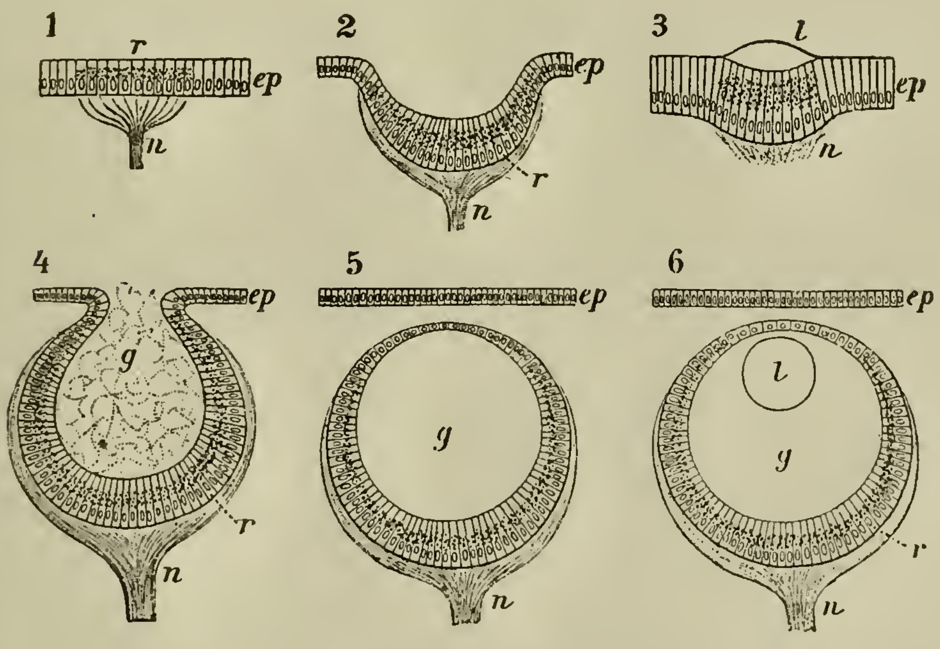
In *Lizzia* (see the figure) the eye is situated at the base of a tentacle and is composed of a lens enclosed in a globule charged with pigment. The crystalline in this hydromedusa is a simple development from the cuticle, while the globe is made up of (a) pigment cells, (b) sensory cells, that constitute the true, retinal element and are attached to a rudimentary retinal rod. Finally, one sees centripetal fibres connected with the ganglionic cells situated at the base of the eye.

Charybdea, a genus of *Cubomedusæ*, has compound eyes, each marginal corpuscle bearing, practically, two large, unequal eyes and four small ones of equal size.



Section of a Larger Eye of the Medusa, Charybdea marsupialis. (Carrière.) 28 x 43 mm.

e, Epithelium of the marginal body; *g*, vitreous chamber; *gl*, ganglion cells; *l*, lens; *r*, retina; *s*, visual cells; *pac*, enlargement of visual cell showing the two extremities and the nucleus imbedded in a pigment mass.

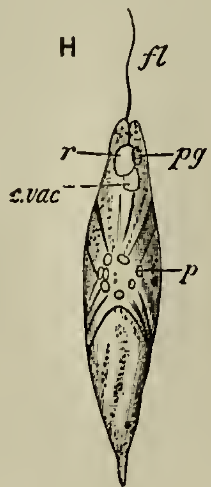


Various Forms of Visual Organs. Schematic. (Boas.)

n, Optic nerve; *r*, retina; *ep*, epithelial layer or modified skin; *g*, vitreous; *l*, lens.

1. Simplest form, as in Medusa and certain Mussels. 2. Open, pigmented cup-form, seen in some Snails and Cœlenterata. 3. To the preceding form is added a lenticular body, as found in certain of the Cœlenterata. 4. The cup-like depression now deepens into a sac with a small opening externally. The sacule may be filled with epithelial débris. This ocular type is to be seen in a few snails. 5. The sac may be entirely closed; the fundal epithelium then becomes thickened and modified as the retina, the thinned epithelium above is the cornea and the interior of the globe is filled with a mass—the vitreous, as in most snails and some caterpillars. 6. With the final development of the lens we have the developed eye of most vertebrates.

The *large eyes* of this genus are well developed and approach in complexity the same organs in the shell-fish, Pecten.



Eye-Spot or Stigma of *Euglena viridis*, the Lowest Organism presenting an "Eye." *fl*, Flagellum or propelling apparatus; *r*, reservoir; *pg*, stigma (eye)— a bright red spot; *p*, paramylum bodies.

Visual Cell of *Limax maximus*. (Grant-Smith.)
k, nucleus; *nf*, nerve process.

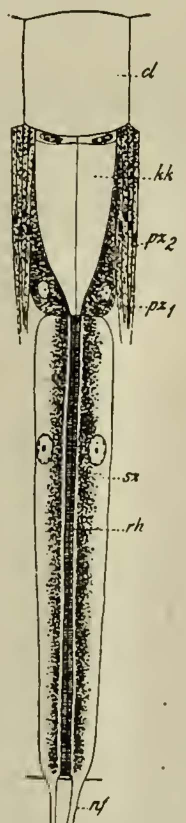
CLASSIFICATION OF THE EYES OF INVERTEBRATES.

From the standpoint of morphology, Hatschek has divided invertebrate eyes into the following categories: (*a*) Eyes formed mainly by

a flattened form of epithelium arranged in the form of a cupula (or cup). (*b*) Cupulate eyes in which, however, the epithelial lining is distinct from the cup itself. Examples of these are seen in Molluscs and Earthworms. (*c*) Eyes with *inverted retina,* i. e., with the rods presenting to the periphery, as in *Pecten* and, perhaps, in the eyes of

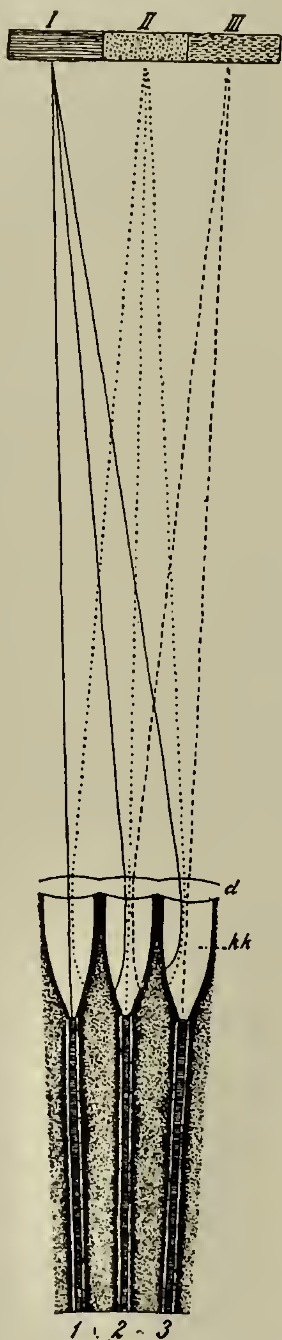
Visual Cells of *Planaria torva.* Schematic. (Hesse.)
sti, Brush-like border; *k,* nucleus; *nf,* nerve process.

Vertebrates. (*d*) The compound eyes of Arthropods (Spiders, Lobsters) and the median cupulate eyes of such animals as present a distinct retinule, Scorpions, for example.



Facetted Member of a Compound Insect Eye (an Apposition Eye). (Hesse.)
cl, Cornea; *kk,* cone; *pz* and *pz_2,* main and secondary pigmented cells; *sz,* visual cells; *rh,* rhabdom; *nf,* nerve duct.

Scientists regard all visual cells as of ectodermal origin. These cells, bearing extremities provided with free neurofibrils, are (1) either surrounded by or included in other epithelial tissues more or less indifferent that enter into the composition of the sensory membrane or of its neighboring structures. These are *epithelials.* (2) The cells are

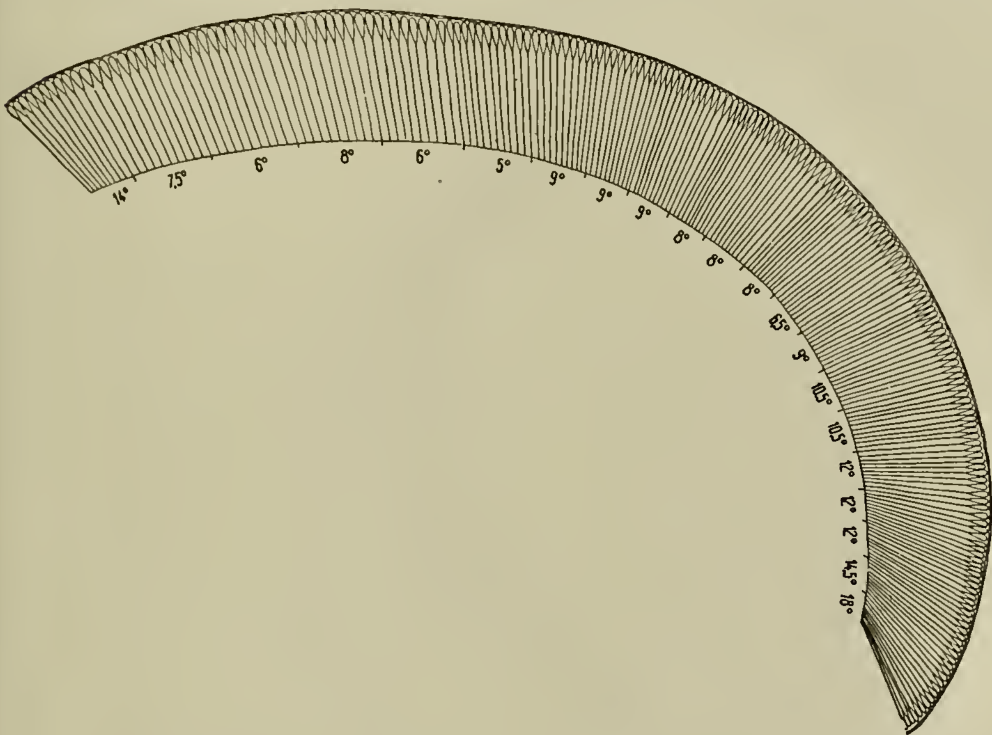


A Diagram of the Vision of the Compound Eye of the *Arthropod* (Apposition Eye). (Hesse.)

The divisions I, II, III, of an object are arranged to correspond to the facetted members, *1, 2, 3,* as their field of vision falls in each case.

buried in the depths of the ectodermic layer and become *intraepithelials;* or they may even develop beyond this situation and become *subepithelials.*

A. The first class (1) comprises by far the largest number of invertebrate eyes. Occasionally the extremities of the visual cells in some members of this class do not exhibit the terminal rods seen in certain Earthworms, Branchiomma, Arca and Pectunculus. Generally, the visual cells present an isolated rod placed on the side opposite the



Frontal Section of the Eye of *Aeshna,* a Dragon-fly. (Hesse.)
The numbers give the degree of the visual angle, which is taken from every tenth facetted member of the row, or in other words, it gives the divergence angle which the axes of the first, eleventh and twenty-first members make with each other.

junction with the corresponding nerve fibre. These elements are (*a*) either situated on a plane surface or are distributed at the bottom of the cupulate excavation. Eventually the cupule may evolve into a vesicle, when the ends of the visual cells are provided with a rod turned towards the interior of the vesicle (*b*); or the same structural changes occur except that the terminal rod points towards the external wall (*c*).

Again referring to the foregoing classification, (*a*) cuplike, or cupulate eyes are found in (1) Annelids (Worms) not only in the fixed varieties but in the carnivorous species.

They are also found in (2) Molluscs, where, for example, they con-

stitute the cephalic ocelli of the Lamellibranchiata; the eye-spots at the margin of the mantle of Lima; the eyes of Patella, and Haliotis, and the eye of Nautilus.

Among (3) Arthropods, we see them in the larvæ of Insects; as the ocelli or *stemmata* of Insects; the lateral eyes of Scorpions, and the compound eyes of all the Arthropods.

We find (*b*) *vescicular* eyes whose retinal rods are turned towards the center of the eye in certain Annelids, in Nereis and Alciopedes. Among *Molluscs* we see them in most Gasteropods and the dibranchiate Cephalopods.

Section of the Facetted Eye of the Praying Cricket *(Mantis religiosa)*. (Hesse.) *ventr*, Ventral side.

(*c*). Vesicular eyes whose rods are turned towards the periphery (inverted retina) are absent in *Annelids*, but they are found in *Molluscs*, in *Pecten*, *Spondylus*; and *Onchidium*.

Among the Arthropods they are to be seen in Spiders and, as median eyes, in Scorpions.

In the category of eyes of the epithelial cellular type one places the intracerebral visual organs both of the Ascidian larvæ and of vertebrates.

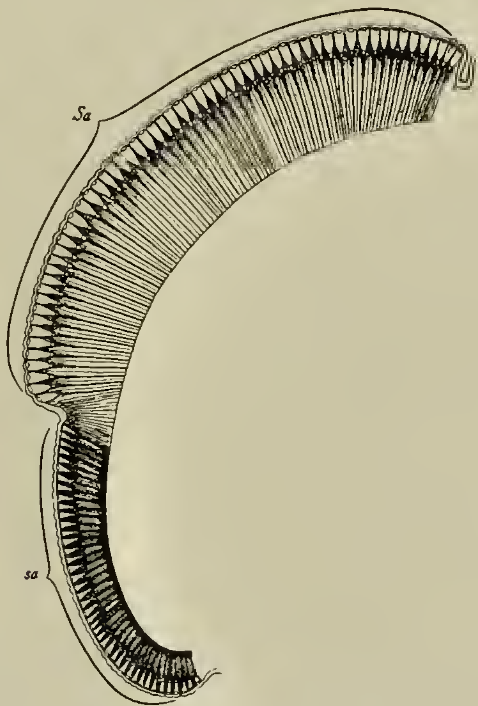
B. Eyes formed of subepithelial visual cells are provided with a terminal fibrillar apparatus buried in the bottom of a cup-shaped space formed by a special variety of pigment cells. The end of the

cell external to this cup, provided with a nervous prolongation, is turned around—in the sense of the incident light rays. In other words, the eye is "inverted."

Pigment is not really necessary to these elements; it is absent, for example, from the single visual cells of Hirudines (Leeches).

To this class of eyes belong the visual organs of (?) Nemertes and Turbellaria among the *Plathelminths*, the median eyes of many adult Crustaceans, and the ocelli of the Trochophorian larvæ.

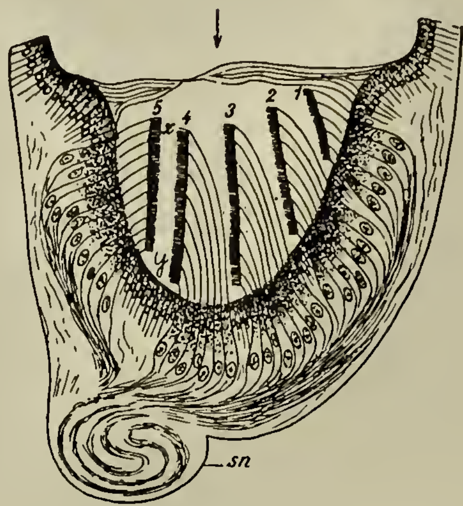
Several *classifications* have also been made on a purely *physiological basis*. For example, Hatschek draws our attention to the fact that



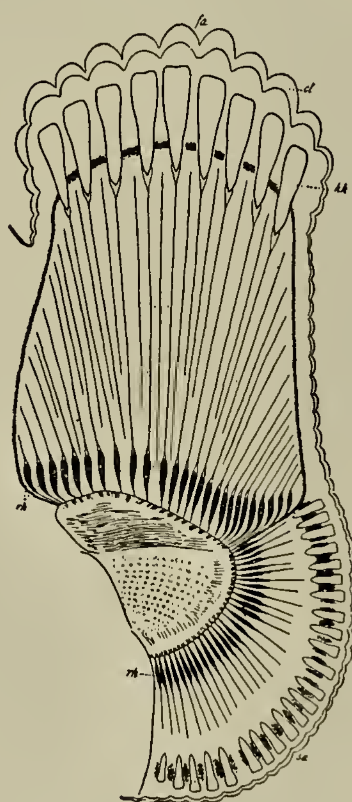
Frontal Section through the Facetted Eye of the Male of *Bibio marci*, a Small Fly. (Hesse.)
Sa, Front eye; *sa*, side eye.

the simplest forms of the visual apparatus have for their function only the determination of the *direction from which light rays reach the eye;* in animals that have for any reason lost their eyes mere luminous impressions are obtained. Other eyes, in the form of a *camera obscura*, are constructed for the more or less clear perception of definite images; while in compound eyes partial images are grouped mosaic-like to reproduce the object.

Compound eyes are found (in their highest development) not only in Crustaceans and Insects, but in certain Worms (*Branchiomma sabella*) and in some Lamellibranchiates (Arca, Pectunculus). They resemble somewhat the eyes of Myriapods (*Scutigera*).



Cross-section Through the Retina of the Invertebrate *Pterotrachea mutica.* (Hesse.)
1-5, First to fifth groups of visual cells with their brush-like borders; *sn,* optic nerve; the arrow shows the direction of entrance of the light rays.



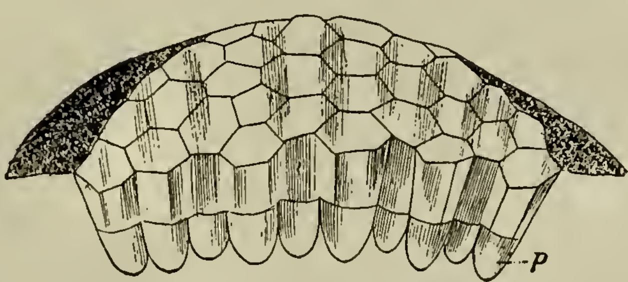
Facetted Eye of a Deep-sea (Invertebrate) Chizopod *(Stytocheiron mastigophorum).* (Chun.)
fa, Front eye; *sa,* side eye; *cl,* cornea; *kk,* crystal cone; *rh,* rhabdom.

The *Medusæ* have a crystalline lens whose elevation above the surrounding surface is quite noticeable—externally. The eye itself consists of a cavity lined by the retina. The anterior wall is formed by general (body) epithelium. The lens is relatively large and cone-

shaped, the apex of the cone extending to the fundus oculi. (See the figure.)

Visual Organ of *Branchellion torpedinis*. (Hesse.)
sz, Visual cell; *p*, pigment wall.

Echinoderms. The Sarasins discovered in the Indian Ocean a Sea-Urchin—*Diadema setosum*—very sensitive to light. The body surface, as dark as black velvet, is spotted over with bluish maculæ—the visual organs. The microscope resolves the surface of these colored areas into several hundred polygons with five or six sides. These polygonal figures represent refracting pyramids that accurately fit one another, the whole body being surrounded by the pigmented integument. The blue color of these eyes is really an interference effect.



Section of a Compound Eye of a Sea Urchin, *Diadema setosum*. (Sarasin.)
p, Pigmented polygonal bodies.

The crystalline exhibits a peripheral cellular band or layer, while its center is made up of soft matter. The space surrounding the lens is filled with the gelatinous mass of the vitreous. The *retina* is composed of cells of pigmented supporting material, arranged pallisade-like, and of long sensory cells.

The *second pair of eyes* in Charybdea are smaller than that just described and pictured. It is provided with a lens supported by a column of tissue that arises from the parts surrounding the globe,

pierces its wall, extends from the fundus, and is inserted into the posterior aspect of the lens. To the periphery of the crystalline is also attached a transparent cellular mass whose purpose is unknown.

In certain Syphonophores one sees certain ocular spots (*ocelli*) that are occasionally provided with lenticular bodies.

Visual Cells of *Turbo (A)* and *Pecten* (B). Schematic. (Hesse.) nf_1, Nerve fibrils; *nf,* nerve process.

THE EYES OF WORMS.

Of all the Metazoa the Flat Worms have eyes that most nearly resemble the Cœlenterata. All the Flat Worms are animals that exhibit a symmetrical bilaterality; i. e., one may distinguish a front and a back, a right side and a left. The sense organs are placed where they will be of most use, viz., in the segment that is in the front of the animal when crawling.

The development of these organs is in keeping with the animal's mode of life. One, consequently, finds the best developed eyes in the free Turbellaria; in the parasitic Trematodes they are decidedly degenerate, while in the Cestodes they are entirely wanting.

All the Polycladida have a large number of eyes, often several hundred. A collection of eyes is found above the brain and on the tentacles. In addition, several species have eyes on the anterior border or even about their circumference. The Triclades have two eyes near

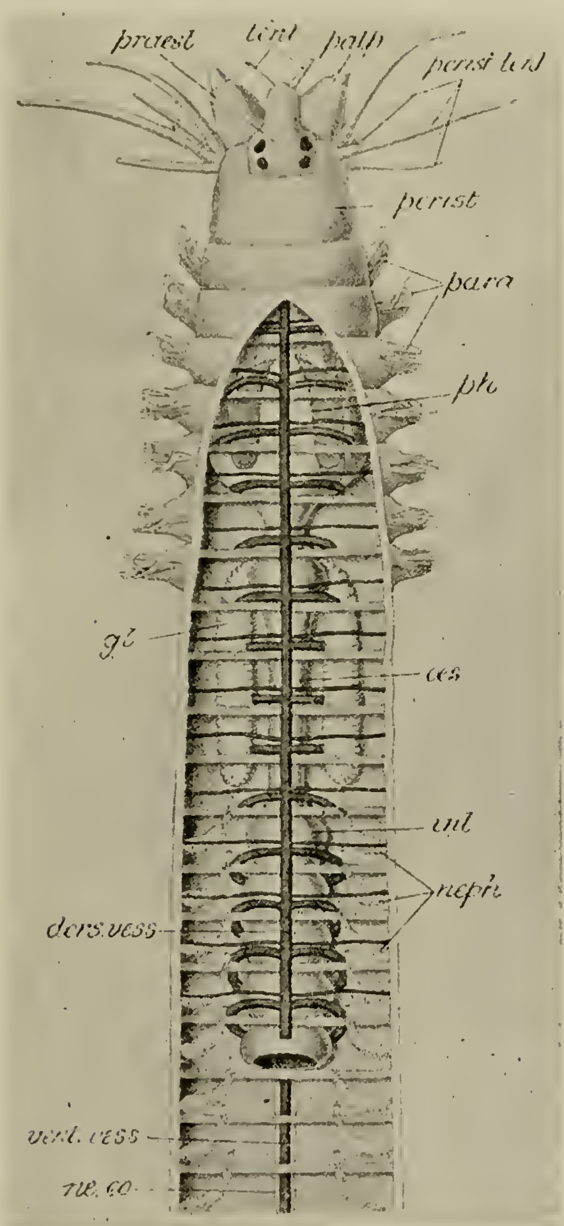
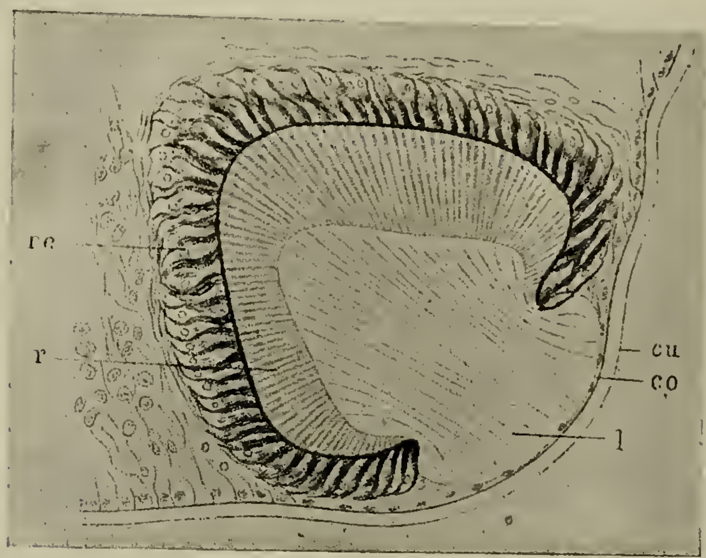


Diagram Showing the Position on the Prostomium *(præst.)* of the Four Eyes of the Marine Worm, Nereis. (After Parker and Haswell.)

the anterior extremity of the body, a large number distributed over the anterior margin or about the circumference of the body. The Rhabdocœlides have, as a rule, two or four eyes, placed directly above the brain or on it.

In nearly all the Platodes the eyes are situated in the parenchyma beneath the epithelium. In Rhabdocœles and the Trematodes they are placed just above the brain or even in its interior. In this way it appears that, in a developmental sense, the primitive site of these eyes is within the ectoderm of the embryo.

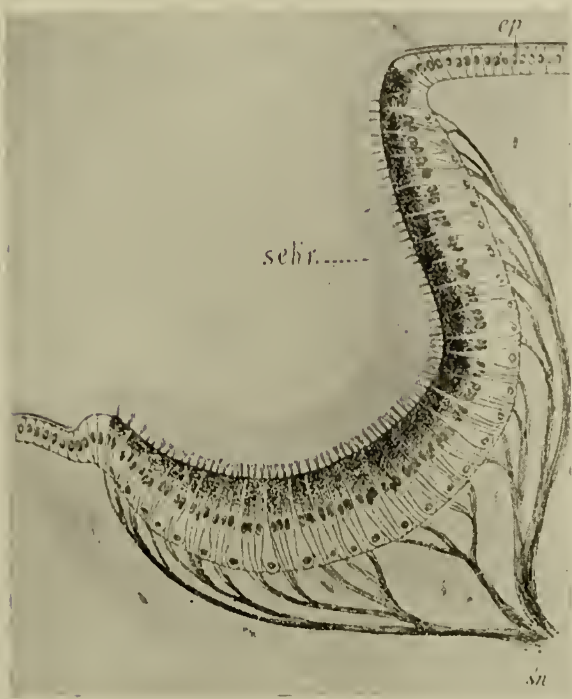
Parker and Haswell (*Text-Book of Zoology*, Vol. I, p. 478) say that of the eyes of jointed worms, Chætopods, their structure "is, as a rule, very simple, but in some forms reaches quite a high grade of development. Usually they are confined to the prostomium, but *Polyophthalmus*, in addition to the prostomial eyes, has pairs of eye-like organs on many of the segments of the body. *Leptochone* has a pair on each



Section Through One of the Four Eyes of the Sea Worm, Nereis. (Andrews.) *cu*, Cuticle; *co*, cornea; *l*, lens; *r*, layer of rods; *re*, retina.

segment, and in *Fabricia* there is a pair on the anal segment; while in many species of *Sabella* and all the species of *Dasychone* there are eyes or eye-like organs on the branchial filaments.

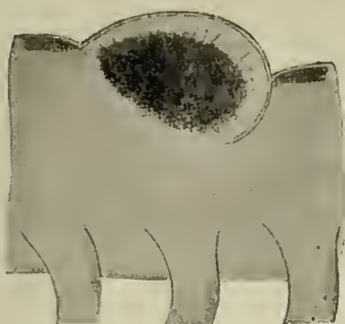
Most usually the eye is (as in Nereis), a spherical capsule with a wall composed of a single layer of cells, which are elongated on the inner side, i. e., the side turned towards the brain, while on the outer side they are usually flattened. The outer thin part of the wall of the capsule, or *cornea*, is sometimes united with the epidermis; when the two layers remain distinct, the outer one is the *outer cornea*, the inner the *inner cornea*. In many cases a thickening of the surface cuticle over the cornea forms a *cuticular lens*. The cells of the inner portion of the wall of the capsule form the elements of the *retina*: they are long narrow cells, sometimes composed of three distinct segments—(1) a clear *rod*, directed towards the central cavity; (2) a mid-



Epithelial Pigmented-cup Ocellus from Patella. Schematic. (Hesse.)
ep, Epithelium; the mass of secretion covers the visual epithelium, which consists of pigmented visual cells and secretive cells, which are free of pigment; *sn*, optic nerve.

Epithelial Pigmented Goblet Ocelli with Alternate Visual Cells on the Gill of *Hypsicomus stich. ophthalmus.* (Hesse.)

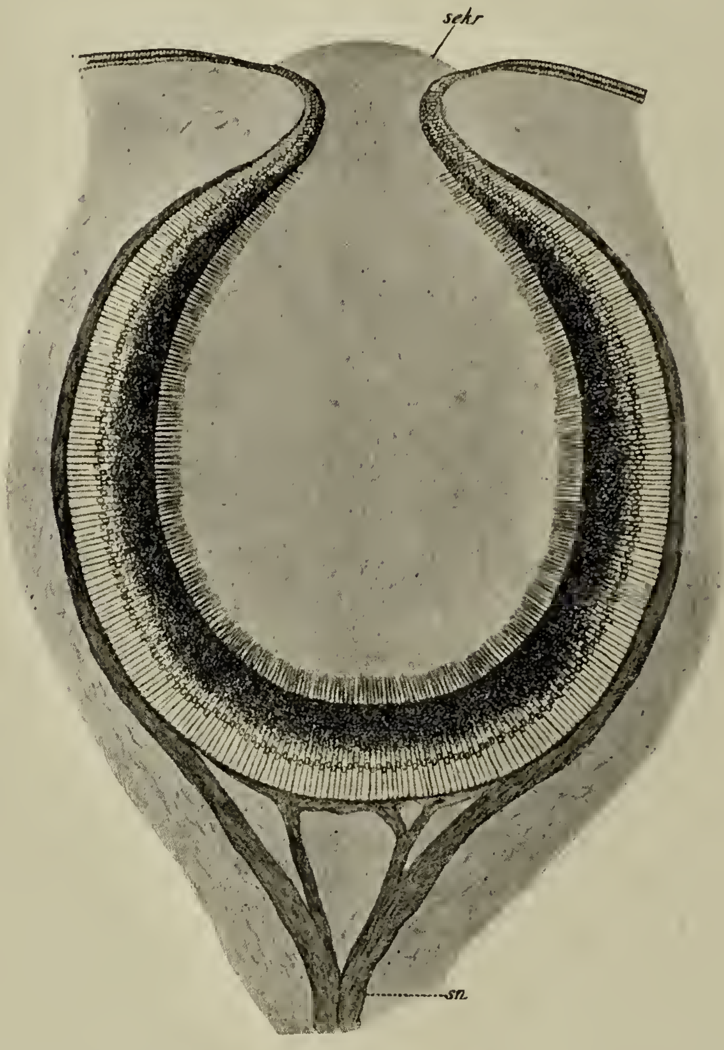
The same on the Gill of *Protulla protulla.* (Hesse.)



The same grouped into Compound Ocellus upon the Gill of *Sabella reniformis.* (Hesse.)

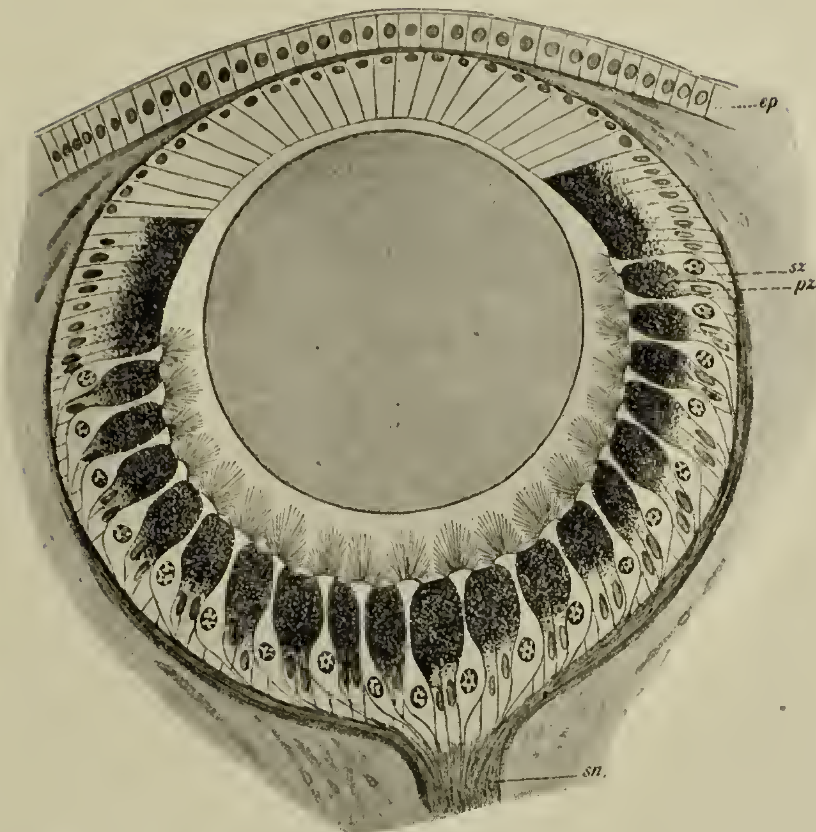
dle segment which is densely pigmented; and (3) a segment containing the nucleus of the cell and directed towards the brain or the optic ganglion, with which it is connected by a nerve-fibre.

Frequently the second and third segments are not to be separately recognized, the whole of that part of the cell which contains the nucleus



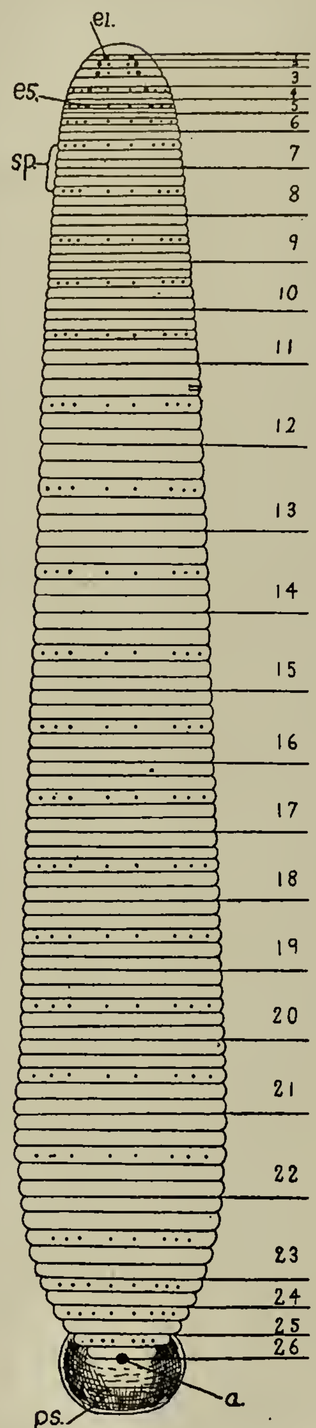
Visual Groove of the Snail, *Haliotis*. (Hesse.)
sekr, Mass of secretion separated from the secretive cells, which lie in the retina between the visual cells.

being densely pigmented. A refractive mass fills the interior of the capsule, and is sometimes distinguishable into a firmer outer part, the *lens*, and a more fluid inner part, the *vitreous body*. This refractive mass is often continuous with the cuticle externally, and internally may be in continuity with the rods. In some cases the structure of the eye is very much simpler. The eyes on the branchial filaments of many tube-forming Polychæta consist each of a group of retinal cells



Lens Ocellus of the Vineyard Snail, Helix pomatia. Schematic. (Hesse.) *ep*, Epithelium; *sz*, visual cell with brush-like border; *pz*, pigment cell; *sn*, optic nerve. The space between the lens and the retina is filled with masses of secretion.

Eye of Pterotrachea coronata, Enlarged twenty times. (Hesse.) *c*, Lens; *f*, window; *sn*, optic nerve.



Dorsal Aspect of the Medicinal Leech—*Hirudo medicinalis.* (After Parker and Haswell.)

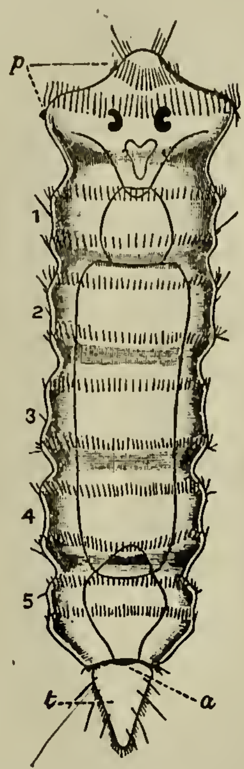
a., Anus; *el.*, first pair of eyes; *es.*, fifth pair of eyes; s. p., segmental papillæ, ps., posterior sucker.

having its own lens-like body and is quite independent of the others; the eye is thus a *compound* one."

Eyes of Leeches. The visual organs of these well known animals

are made up of a single visual cell, or numerous cells united in groups about a pigmented capsule. In the former instance (*unicellular eyes*) nearly spherical, isolated, cellular elements are found below the epidermis. These are 50 to 60 microns in diameter and are generally seen in the anterior segments, along with (or without) the second variety, multicellular organs.

The Medicinal Leech has ten (i. e., 5 pairs of) eyes; a pair to each of



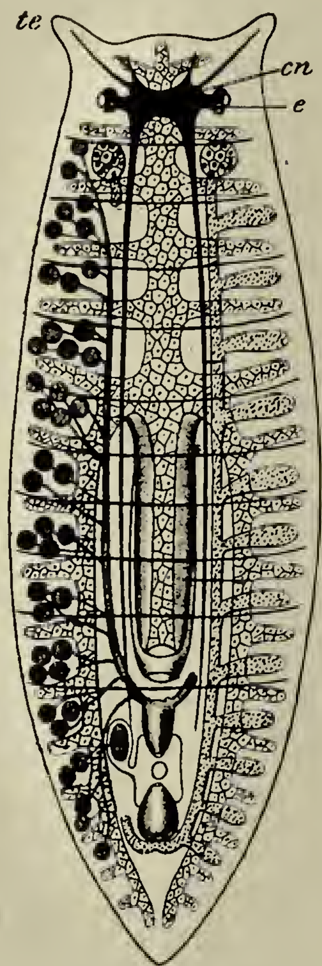
The Paired Eyespots of the Minute Worm, *Dinophilus*.
The black, kidney-shaped markings near the blunt end or head are the eyes. (After Sheldon-Harmer.)

the five sections about the margin of the anterior sucker of the animal. These ten "eye-spots," so easily seen, have analogous sense organs in all the other sections.

The histology of these ocelli is peculiar and interesting. They are of cylindrical form, the long axis of the cylinder being at right angles to the body surface.

The body of the Medicinal Leech (*Hirudo medicinalis*) has 102 rings, of which 26 are distinguished by the presence of segmental papillæ. A pair of eyes is placed on the dorsal aspect of each of the first five segments. (See the illustration.)

Eyes of the Turbellaria. The *Planaria* carry, in the subdermal parenchyma, a pair of eyes at the anterior extremity of the body, in the shape of two minute, pigmented points, about the tenth of a millimeter in diameter. They form a single or many-celled pigmented goblet, which receives the enlarged, button-shaped extremity, or cone, of visual cells.



Paired Eyes of a Flat Worm, *Triclad.*
cn, Brain; *g*, germarium; *e*, eye.

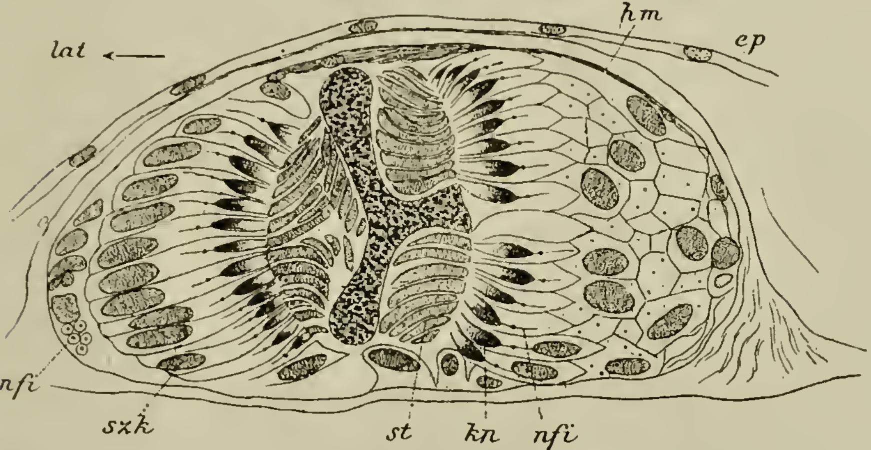
The number of these cellules varies from 1 to 150. The retina (*retinule*) or optic ganglion is represented by a mass of visual cells situated outside the pigmented cup. The optic nerve, formed by the union of the retinal fibres, is connected with the nervous substance that represents the brain.

In the Polyclades the minute ocular structure is essentially the same as in the Triclades.

Eyes of the Trematodes. According to Hesse (*Das Sehen der niederen Tiere,* 1908) the eyes of the Worms Tristomum and Polystomum closely resemble in structure the ocular organ of the Triclades.

Eyes of True Worms. These vary greatly, from simple "eye-spots," or mere collections of pigmented cells connected with a few nervous filaments, to eyes provided with a retinule, lens, etc. The parasitic worms have the least developed eyes, while some worms are blind.

The absence of eyes is the rule in Nemathelminthes.



Section of the Eye of a Chetognath *(Spadella hexaptera)*. x 900. (Hesse.) Three pigmented cavities have been opened by the section. The visual cells with their nuclei *(szk)* show, in the interior of their extremity, a black nerve filament *(nfi)* that is continued by a sort of elongated process and a rod.

The eyes of *Chetognaths* are two in number, borne on the head in the form of aplaties spheres. The illustration (Hesse) gives an idea of this rather complicated ocular organ.

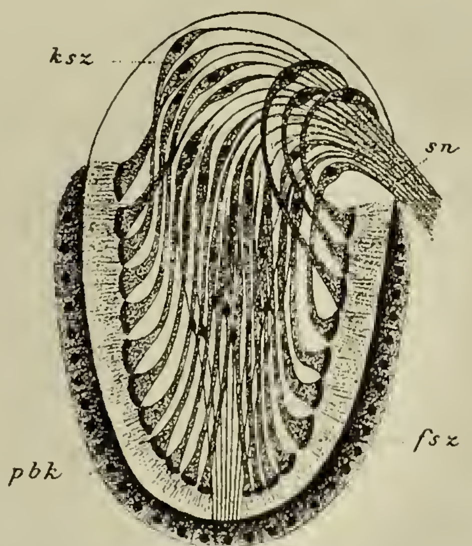


Diagram of the Developed Eye of a Nemertean Worm. (Hesse.) *pbk*, Pigment layer; *fsz*, nerve fibre cells; sn, optic nerve.

Eyes of Nemerteans. These non-parasitic unsegmented and mostly marine worms generally have eyes, although some are blind. In the more highly organized species the ocular organs are very numerous.

The eyes are structurally simple in some; quite well developed in others. The latter have a cupulate refractive body, a cellular vitreous and a retinule consisting of a rod layer enclosed in a dark pigment sheath, each rod having a separate nerve-branch connected with it.—(Parker and Haswell.)

These worms are closely related in all their organs to the Turbellaria, as will be seen by the illustration.

Eyes of Annelida. Eyes are well distributed among all varieties of these segmented worms, both fixed and free, their number, structure and position depending upon the habits of the animal. Several Serpuzians have eyes on their cephalic branchia; Protula carry them on a colarette that surrounds the orifice of the tube, while in Fabricia, whose tubes are only temporary dwellings, the anterior eyes are smaller than a second pair placed on the anal segment, posteriorly.

Vermilia infundibulum has on the external aspect of each branchium at least 220 ocelli, in all 11,000 cephalic eyes.

The number of these cephalic eyes varies from one family and even from one species to another; in fact, a study of the eyes of Worms furnishes the most varied examples of ocular organs, from the simple, pigmented "eye spots" commonly seen in Cœlenterata to the complex and developed eye, provided with a lens, etc., of Mollusca. In this connection one may speak of the *simple* eye as constructed of elongated epidermal cells charged with pigment at their inferior part. A nerve filament joins each cellular base with ganglion cells. An ocellus is composed of a single visual cell.

In eyes of epithelial structure the visual cells are formed at the expense of the epithelial cells of the exterior tissues. These eyes are held in the substance of the epidermis, and the visual elements of which they are composed send out a nerve fibre towards the nerve centres. In contrast with those eyes that are situated in the epidermis, the epithelial eyes establish themselves on the surface of the membrane and the visual cells which constitute them keep their plunge in the range of the neighboring undifferentiated cells.

Forms of the ocular apparatus in Worms. Let us review these different types. Kalt (*Encyclopédie française D'Ophtal.,* III, p. 705) divides them into the following types:

A. *Eyes in the form of a cup.* These are found in Capitellidæ, which have as many as two hundred small pigmented pockets on the dorsal surface of the head on each side; *Polyophthalmus* has two eyes upon a great many of its segments. These eyes are situated underneath the epidermis on the lateral lines of the body. Analogous structures are found in the larvæ of Annelids.

B. *Epithelial eyes without a crystalline lens for each separate element.* These are rarer than the cupulate form. After removing the end of the rods the center of the plate tends to become invaginated in the integument. These eyes are found in the Chetopteridæ where the visual cells cover tubes whose axis is perpendicular to the integument.

C. *Epithelial eyes furnished with a crystalline lens for each element.* Only the Serpulacea are provided with this sort of eye. These are found on the segments of the body, more often disposed in rows upon the branchial filaments. The elements are solitary, slightly grouped or united in the form of a fan, as in the eye of the Arthropods.

Branchiomma bears, near the end of each branchial filament, a compound eye which surrounds it almost completely.

The eye is composed of ommatidia, each provided with a hemispherical lens. The elements are separated by pigmented cells which enclose each ommatidium, as in the compound eye of the Arthropods.

Analogous eyes are found in Sabella reniformis. These animals are very sensitive to the light and perceive small differences of light and dark. After section of the branchial filaments bearing the eyes of a Branchiomma, the animal is almost indifferent to variations in illumination.

A curious thing is that if these eyes be cut out they regenerate themselves very quickly in the course of a few days.

The eyes of free Polychetes. Carnivorous Annelids. The eye has the form of a round or ellipsoidal vesicle situated immediately below the cuticle. Except in a small portion situated on the surface of the body, the wall of the vesicle is formed by a layer of pigmented cells. The ends of the cells turned towards the cavity of the eye have an elongation in the form of a characteristic rod of sensory cells. Many authors, Jourdan among others, incorrectly describe this layer as a vitreous body, reserving the name crystalline lens for the mass which fills the ocular cavity.

According to Hesse, *Nereis cultrifera* possesses four eyes, two on each side of the head. The axis of the anterior eye is directed outwards and forwards; the posterior pair look outwards and backwards. These organs are placed in the substance of the epidermal covering, which is quite thick in this region. They are covered by an epidermal cuticle and rest upon a basal membrane which is not interrupted at their level.

In the retinal layer may be seen two sorts of elements: visual elements and secretion cells. The latter are much less numerous than the former. The visual elements are large and distinctly colored; their nucleus is situated deeply with the end turned towards the cavity

of the eye. It is provided with a rod while the other end is drawn out to form a nerve fibre.

The optic nerve penetrates directly into the brain. Nevertheless, in Nereis, in the rear of the anterior eyes, is a layer of large ganglion unipolar cells, that constitutes the optic ganglion.

The ocular organ of Alciopides attains a high development. The eyes, two in number, form a round protuberance on each side of the head. They have the form of an ellipsoid whose axis coincides with the optical axis. The epidermis with its cuticle covers the organ and forms in its center the external cornea. The ocular vesicle, completely closed, is made up of a cellular layer, which, in front, forms the internal cornea (covered by the integument or external cornea), and at the back, the retina. There is, also, just behind the cornea, a spherical crystalline lens and a vitreous body with a special secretory apparatus.

Three portions may be distinguished in the ocular vesicle, first, an anterior hemispherical part, corresponding to the cornea, which contains no pigment. A middle portion reaches from the cornea to the neighborhood of the ocular equator. It is formed of short cells enclosed in pigment, and corresponds to the ciliary body of vertebrates. The third portion, which occupies all the fundus of the vesicle, is entirely made up of the retina.

The elements of the retina are elongated cells, very much crowded together, in which three layers may be seen; the body of the cell itself containing the nucleus turned from the side of the brain; the rod turned from the side of the entrance of light rays, and a layer of pigment localized between the two parts.

The *intermediate zone* of this vesicle is covered internally by short cells provided with pigment cells at the level of the internal margin. To a certain extent, in the inferior-internal portion of the globe, these cells suddenly increase in height, and their protoplasmic body extends over the pigmented layer into the ocular cavity. These cells may secrete the aqueous humor.

On the inferior-internal side of the globe, at the level of the anterior terminations of the retina, is found a depression corresponding to the duct or opening into the gland of the vitreous body. This gland is, according to Kleinenberg, continued as a single space of considerable volume, in the form of an elongated sac. The cell contains a thick oval core, partially fitted into a protoplasmic mass traversed by dark undulating lines. The products of secretion escape into the excretory canal of the gland, and is in contact with a portion of the nucleus, and thence reaches the vitreous body.

The vitreous humor is a viscous mass, touching, in front, the crystalline lens. Behind, it does not quite reach the retina.

Below the external layer of the cornea, Hesse found and described a layer of elongated muscle fibres which constitute part of an accommodative apparatus intended to modify the curvature of the ocular wall and to displace the crystalline lens.

In some *Alciopides* the fibres of the optic nerve emanating from the retina go directly into the upper œsophageaz ganglion, situated near the eye. In *Vanadis* these fibres cross a true ganglion formed by large cells with a unipolar appearance. From this is detached the optic nerve proper.

THE VISUAL ORGANS OF MOLLUSCS.

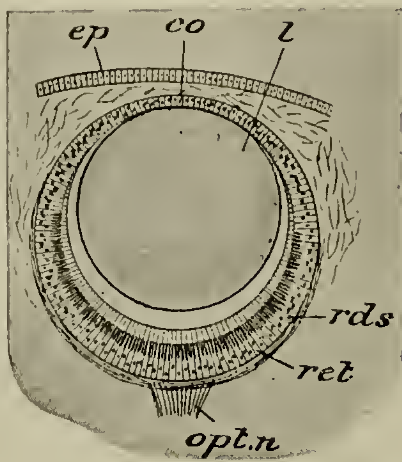
Molluscs have generally two cephalic eyes, although these organs are lacking altogether in the Scaphopods, the Amphineurans, the majority of the Pteropods, many adult Lamellibranchiates, and a number of Gasteropods.

These cephalic eyes may be replaced by eyes scattered over the dorsal region, as in certain Chitonidæ, or, as in the Lamellibranchiata, by eyes occupying sometimes the margin of the mantle, sometimes at the end of the tentacles of the syphons. Analogous dorsal eyes accompany the cephalic eyes in the Oncidiidæ. Even when these Molluscs have no eyes the skin has a certain sensibility to the light.

The *dorsal eyes of Amphineurans,* especially in Chitonidæ are, according to Moseley, a modification of certain organs of general sensibility, which are called, according to their size, *microesthetes* and *megaloesthetes.* Thèse are the epithelial papillæ covered, each, by a cephalic hood. These papillæ contain nerve ends and each receives a special nerve. The nerve corresponding to a megalaesthete gives off, generally, several branches that join the microesthetes. The dorsal eyes are modifications of certain megalaesthetes. Each one of these is made up of a deep retinal cup, a crystalline lens, and a calcareous cornea; the whole is surrounded by a pigmented envelope. These eyes are situated upon the lateral segments or along the line which separates them from the middle area; they are lacking in most European species, in the large Chiton of South America and in Chitonellus. All these organs are replaced in Neomenidiæ by simple dermal papillæ imbedded in the cuticle.

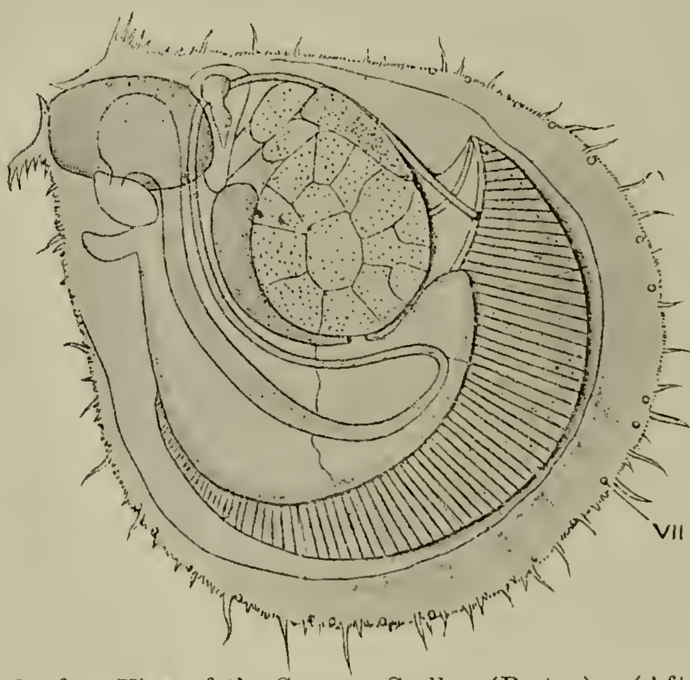
The *eye of the Mollusc Triton* (English Whelk) is a well-formed organ. According to Parker and Haswell (*Text-Book of Zoology,* Vol. I, p. 731) it forms (see the cut) a rounded invagination of the epidermis with an inner wall or retina composed of pigmented and sensory cells. "The latter (retinophores) are elongated cells narrowed at

their central free ends, and produced at the opposite extremity to become continuous with nerve-fibres of the optic nerve. The former retinulæ) have their free extremities much enlarged, and surround the



Section of the Eye of Triton, or English Whelk. (Parker and Haswell.) *co*, Cornea; *ep*, epidermis; *l*, lens; *opt*, optic nerve; *rds*, layer of rods, *ret*, retina.

slender ends of the retinophores. A layer of short rods lies within the retina proper. The outer wall is thin, and, with the overlying epidermis, forms a transparent cornea. In the interior of the eye is a clear

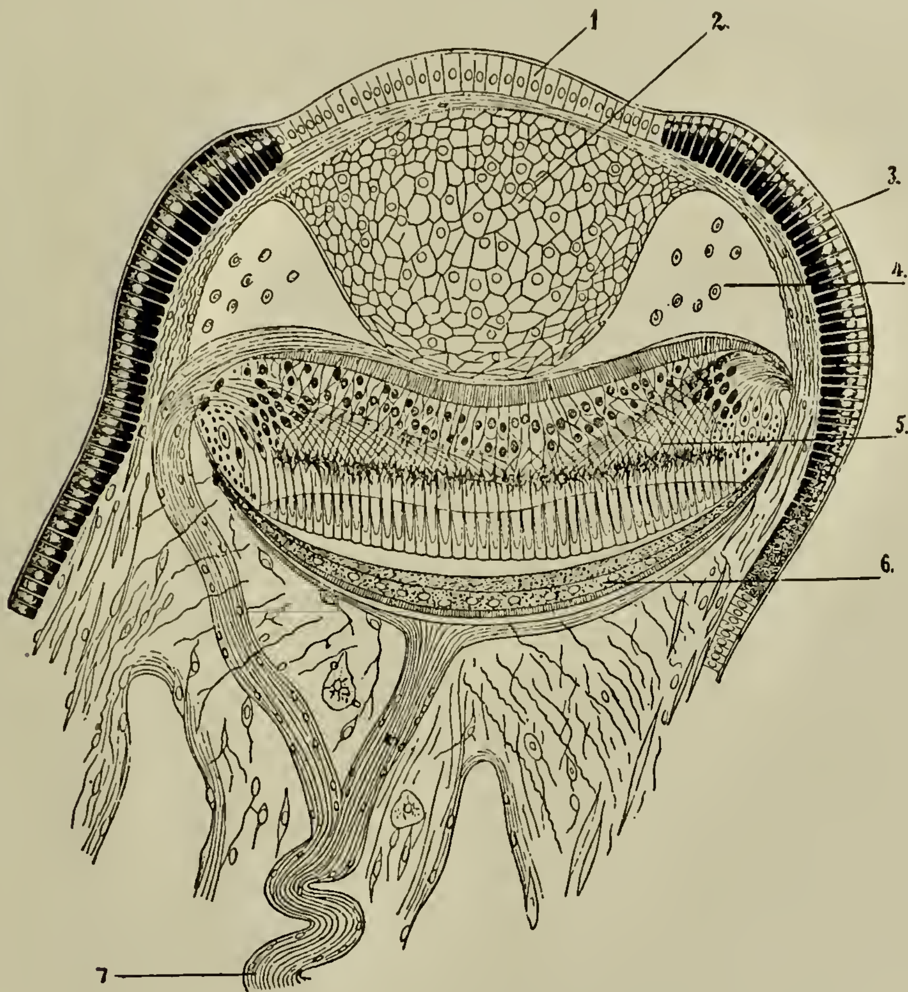


A Single Surface View of the Common Scallop (Pecten). (After Pelseneer.) One of the pallial eyes—arranged along the margin of the mantle—is shown at VII.

rounded lens of dense cuticular matter secreted by the cells of the retina. This is surrounded by a less dense vitreous body."

Eye of the Common Scallop (Pecten). This shellfish has its eyes in

the only situation that it is likely to be of use—in a single row all about the margin of the mantle—as shown in the figure. Each of these pallial eyes has a cornea, a cellular lens, a retina provided with rods and an optic nerve. Thus, Pecten has, for a mollusc, a highly developed visual organ, as portrayed in the accompanying figure.



Section of the Pallial Eye of Pecten. (Korschelt and Heider.)
1, Cornea; 2, cellular lens; 3, external epithelium; 4, vascular sinus; 5, retina; 6, pigment layer; 7, optic nerve.

Kalt describes the eyes of the Scallop as brilliant points, shining with an emerald green or purple reflection. They are variable in number according to the species: 28 to 46 have been counted in the upper half of the mantle, 15 to 36 in the lower half. Their diameter is 0.6 to 0.8 mm. According to Carrière, their number increases with age in the same individual.

The eye is borne by a pedicle more or less large and contractile. It is surrounded by connective tissue which is condensed in the anterior

part to a sort of cornea. The superimposed epithelium, elsewhere strongly pigmented, becomes short, colorless cells on the cornea and makes up a sort of external pupil. The eyeball, of ellipsoidal form, with a long transverse axis, receives a nerve filament in two unequal parts. One of these more slender than the other spreads out upon the fundus of the eye, while the other passes towards the anterior part of the globe to be distributed to the retina. (See the illustration.)

Eyes of the Lamellibranchiata. Pelseneer has discovered in Mytilus and Avicula paired eyes situated at the base of the first internal branchial filament. This cephalic eye is a larval remnant, which escaped observation for a long time because of its small size. It is due to the invagination of the teguments and recalls by its structure the eye of Patella. The cavity contains a refracting cuticle mass; the retina is formed by two kinds of cells: clear cells with a large nucleus and pigmented cells.

Generally, the eyes of the Lamellibranchiata occupy either the margin of the mantle, as in the Pectinidæ, or the extremity of the tentacles of the syphon, as in Cardium edule.

According to Will, Carrière and Patten, the ocular organs of the Shellfish Noah's Ark are compound eyes, whose structure resembles the eyes of insects. This animal is extremely sensitive to the slightest change in illumination and it never fails to close its shell when the shadow of an object falls upon it. The edge of the mantle is provided with three longitudinal ridges separated by furrows. The middle ridge, called the ophthalmic fold, has pigmented pockets that indicate the position of the eyes.

Patten counted 235 of these in one animal. Each eye contains 10 to 80 elementary eyes, or ommatidia.

The ommatidium is composed essentially of a visual cell surrounded by pigmented cells. The visual cells belong to the epithelial type. They are limited internally by the cuticle and rest upon a basal membrane.

Arca and Pectunculus are the only Molluscs that have eyes of the compound type. In Patella, Lima, and Haliotis, the organ is still more simple.

The eyes of *Lima squamosa* appear at the border of the mantle in the form of small dark spots, oval in form, with the largest diameter equal to one-third of a millimeter, and separated by intervals of about 2 millimeters. In Lima, 30 have been counted. They really form small cup-shaped depressions. The epidermal covering of the cupule is composed of sensory and pigmented elements. The latter have, in sections, the form of a triangle whose base is turned towards the apex

away from the surface. The nucleus is found not far from the apex, while the body of the cell is filled with pigmental granules.

The eyes of Pecten and Spondylus have been studied by Patten, Carrière, Hesse and others. In the case of both these shellfish, they are situated on the edge of the mantle, as in those of Arca, Pectunculus and Lima; but that is their only resemblance to the eyes of these animals. They are of a type of which nothing analogous is found either in the Lamellibranchiata or in the Gasteropods.

The interior of the ocular cavity is divided into two compartments by a transverse wall, the septum. The crystalline lens occupies the anterior half, the retina, relatively very thick, the posterior compartment.

The crystalline lens is composed of large cells, crowded together.

It is likely that an accommodative apparatus is present in these eyes. It consists of a thin layer of muscular fibres applied to the anterior surface and upon the equatorial circumference of the crystalline lens, where their ends blend with the capsule. The contraction of this muscular plane is said to produce an elongation of the antero-posterior axis of the crystalline lens and to bring about a convexity of the free posterior surface of the lens.

The *retina* may be considered as formed by a flattened vesicle, with a long transverse axis, whose posterior wall is made up of a single layer of cubic cells, the *pigmented epithelium,* while the anterior wall, enormously developed, constitutes the retina proper.

The extremities (turned back) of the rods are not separated from the pigmented epithelium except by an interposed, thin fibrous layer, the *tapetum.*

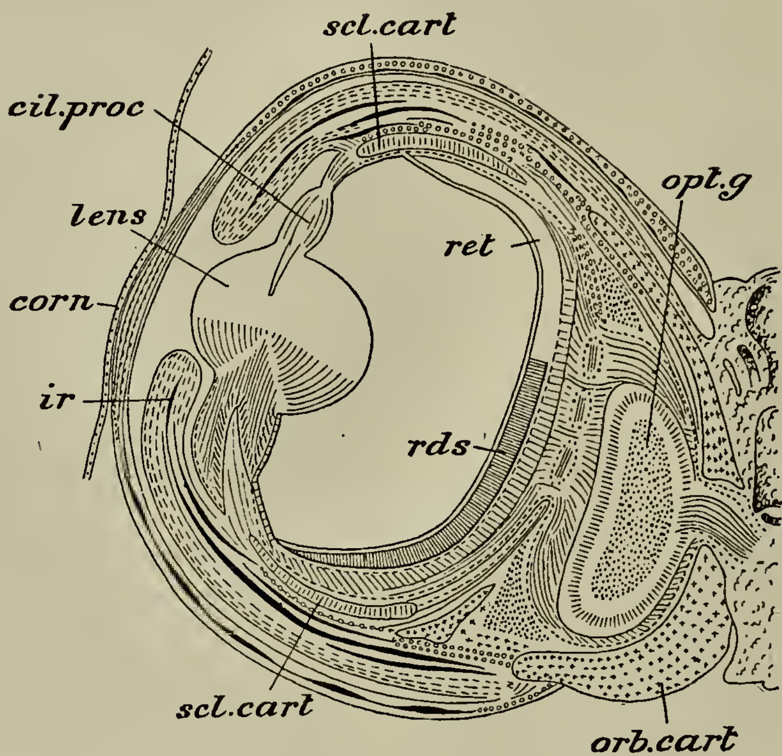
Eyes of gasteropods. These, two in number, are placed side by side in the anterior part of the body, close to the brain. An optic nerve, from the supraesophageal ganglion, connects each eye with the nerve centres. In the Prosobranchia, the eyes are generally borne on an eminence which may not be much elevated or it may take the form of a tentacle.

According to Willem, the position of the eyes of *Opisthobranchia* is variable; they may be quite superficial, be placed beneath the integument or be buried deep in the body tissues.

Very simple forms of eyes have been found in Prosobranchiates, especially in Patella and Haliotis. The ocular organs of the former are borne on the external surface of the tentacles in the form of small black points, and are simple depressions in the integument. In Haliotis these are open vesicles.

The *Cuttle-fish* (Sepia) has a relatively large and remarkable pair

of prominent, lateral eyes that externally resemble the same organs in the higher vertebrates. Sepia has even a pair of ill-developed eyelids and external ocular muscles that permit of some excursions of the globe. The front of the eye is covered by transparent cuticle called the *false cornea,* as shown in the illustration. The sclerotic is strengthened by a ring of cartilaginous plates set about the globar equator. There is a well-developed *pupil* and *iris,* the former being capable of some degree of variation in size.



Section of Eye of the Cuttle-fish. (Hensen.)
cil. proc, Ciliary processes; *corn,* false cornea; *ir,* iris; *lens,* crystalline lens; *opt. g,* optic ganglion; *orb. cart,* orbital cartilage; *rds,* rods; *ret,* retina; *scl.* cartilage, scleral plates.

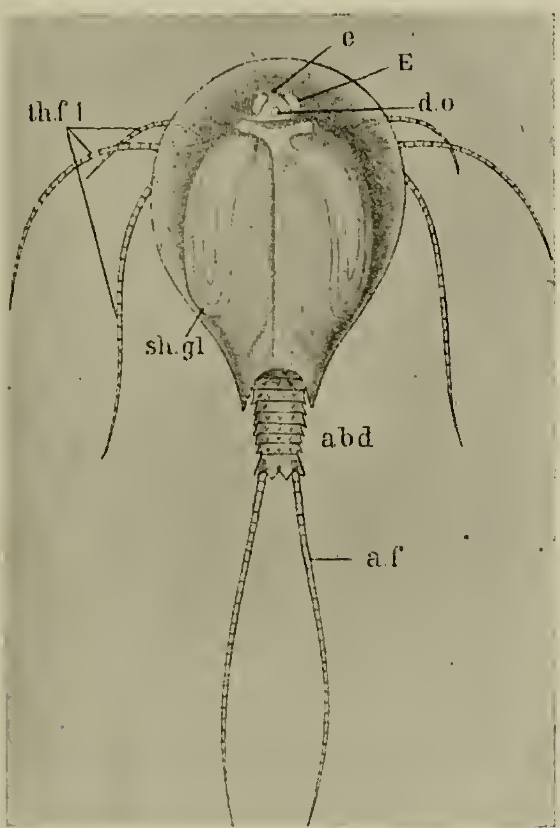
The *lens* has a spheroidal outline and is a dense transparent body apparently constructed of two plano-convex lenses supported by *ciliary* processes that appear to be attached to and to move back and forth with the antero-posterior excursions of the crystalline. In front of these is a plainly marked *anterior chamber* containing *aqueous humor* and behind it the *vitreous body* in its special chamber. This cephalopod eye has also a developed *retina,* the fibres of which, spread over the fundus oculi, are derived from the *optic ganglion.* The *layer of rods* form short, prismatic bodies resting on an outer layer of *optic fibres,* also arising from the nerve-cells of the optic ganglion.

A peculiar, soft and rather large mass situated between the optic

nerve proper and the posterior aspect of the globe is the so-called *white body* or *optic gland,* about whose function little or nothing is known.

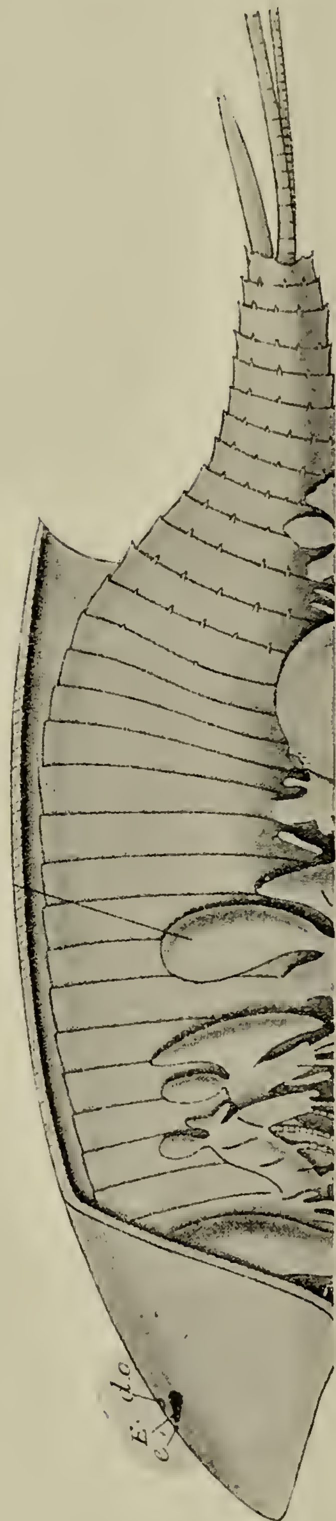
EYES OF ARTHROPODS.

In certain of the smaller *Arthropods,* the *Crustaceans* in particular, the paired eyes are (see illustration) situated on the dorsal surface of the head. According to the description given by Parker and Has-



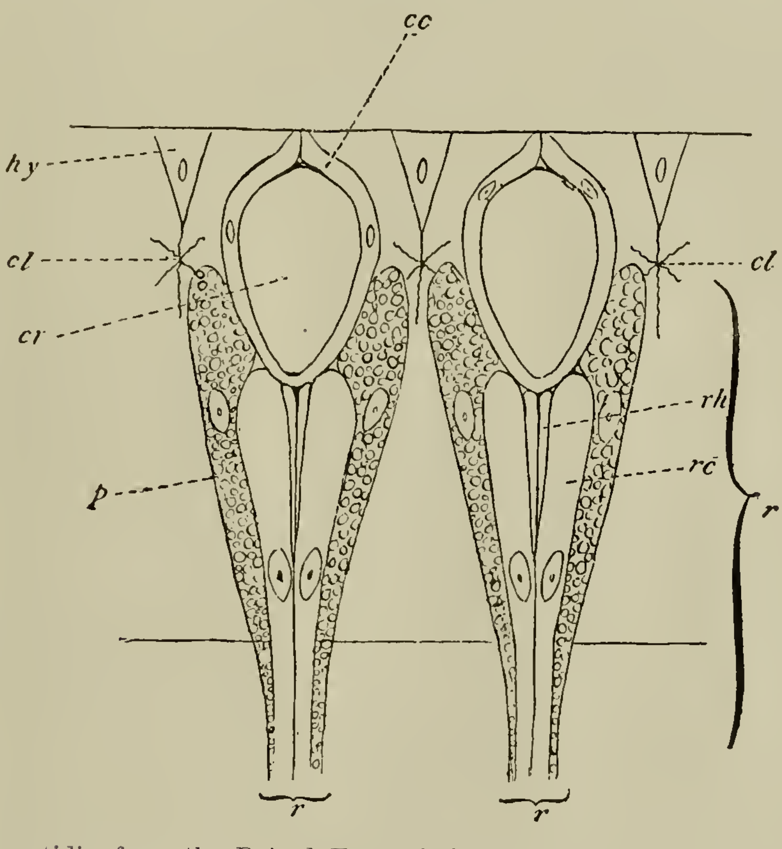
Eyes of the Crustacean, *Apus cancriformis.* Dorsal Aspect.
d. o., Dorsal organ; E, one of paired (lateral) eyes; *e,* single median eye. (Gadow-Bronn.)

well (*Text-Book of Zoology,* Vol. I, p. 536) they are covered by transparent cuticle forming the cornea, beneath which is a narrow space or water-sac, communicating with the exterior by a pore, and therefore filled with water. "The eye itself is made up of a large number of radially arranged elements called ommatidia, each of which consists of an outer and an inner portion. The outer portion is a group of clear glassy cells enclosing a transparent homogeneous vitreous body:



Eyes of the Crustacean, *Lepidurus kirkii.*
Side view with most of the shell removed.
do, Dorsal organ; E, one of the two paired eyes; median (single) eye. (After Parker and Haswell.)

the whole of this portion of the eye serves to refract the rays of light—it is the dioptric apparatus, like our own lens and vitreous humor. The inner portion is a group of sensory cells, constituting a retinula and enclosing a refractive rod, the rhabdome: the retinula is the actual percipient part of the ommatidium, its cells being comparable to our own rods and cones. The retinulæ of adjacent ommatidia are separated from one another by cells full of black pigment, so that each ommatidium is in a state of optical isolation from its fellows, and the whole eye is what is called a compound eye. The optic nerve springing from the brain dilates into an optic ganglion, from which fibres pass



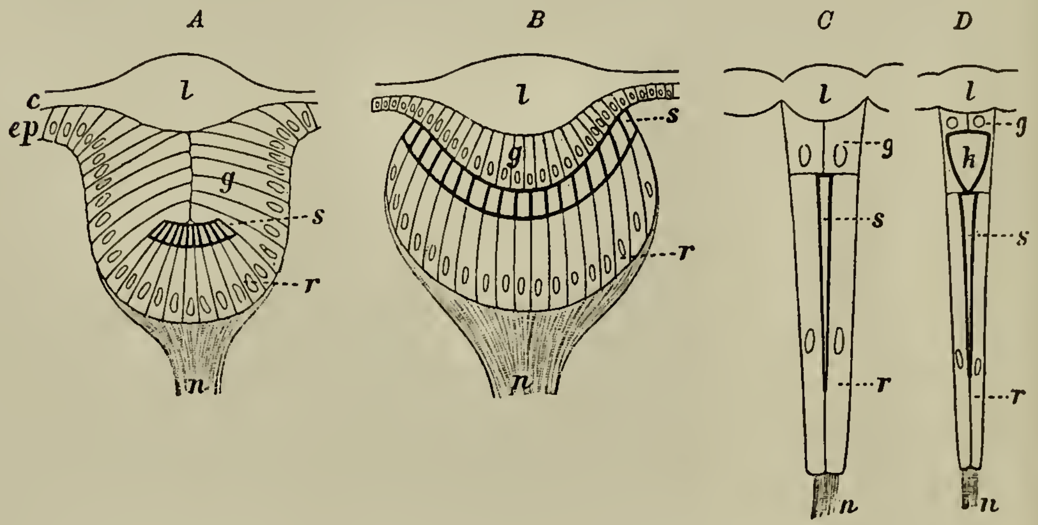
Two Ommatidia from the Paired Eyes of the Shell Fish, *Apus*. (After Parker and Haswell.)

r, Inner portion of ommatidia; *rc*, retinule; *rh*, rhabdome; *p*, pigment cells; *cc*, vitreous cells; *cr*, vitreous body; *cl*, fibre of connective tissue; *hy*, epiderm cells.

to the retinulæ. The medium eye is an ovoid body, and consists of four groups of large sensory cells enclosing a mass of pigmented tissue: it is in immediate contact with the brain, and receives a narrow canal from the water-sac beneath the cuticle of the paired eyes."

The eyes of *Arachnida*—Spiders, Crabs and Scorpions—differ according to the groups to which they belong. They are generally of the simple type one finds in Insects (ocelli), except in the central eyes of

Scorpions (in which there is a vitreous body) and in the compound eye of Limulus. The latter has a chitinous lens-cornea developed from a thickened cuticle. It is not facetted, but internally exhibits a number of conical papillæ, each of which overlies an ommatidium, and is a lens.



Several Forms of the Eyes of Arthropods. Schematic. (Boas.)
A, B, Eye spots; C, D, several "eyes" (ommatidia) of the compound organ of Anthropods.
n, Optic nerve; *r*, retina; *s*, rod from the retina; *g*, vitreous; *k*, crystalline cone; *l*, lens; *c*, the general cuticle of the animal; *ep*, dermal cells.
B, Is found in Spiders, in some Insects and in their larvæ.
Compound eyes, C, D, are seen in most Insects and Crabs.

The eyes of the Scorpion are pictured in the cuts. They are intermediate between ocelli and facetted eyes in that they present the single, cuticular lens of the ocellus and the arrangement in groups, corresponding to the ommatidia. Each retinule is composed of five cells with a single rhabdome or thick axial rod.

Vision (form perception) in Arthropods. Exner, after examining with the microscope the image furnished by the dioptric apparatus, cornea and crystalline cone of *Lampyris,* concluded that the approximate visual acuity is about 6/400. The chief cause, he believes, of the poor eyesight in this genus is the irregular corneal surface and the imperfect centering of the cone with the cornea.

A number of observers have studied the eyesight of insects and have found it, as a rule, defective. Even a wasp chasing flies was several times noticed by Forel to mistake heads of nails (driven into the woodwork) for its prey. Workers among ants often pass close to their larvæ without seeing them.

Visual acuity is more developed in those insects that chase others. Comparatively good eyesight is quite indispensable to them and ocelli cannot take the place of facetted eyes, as proved by the experimental covering of the latter with an opaque varnish. Flies, Cockchafers and Wasps do not pursue their prey, or if they attempt to do so they col-

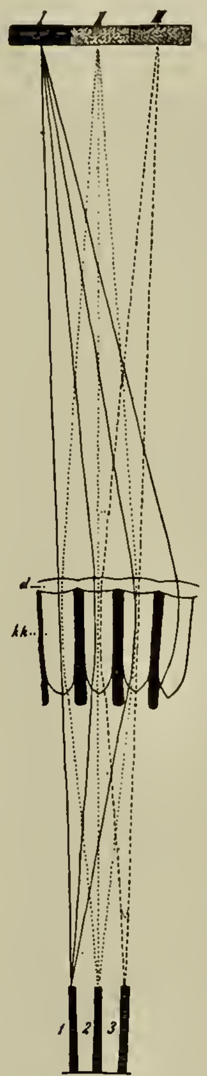


Diagram of Vision with the Compound Eye of an Arthropod (Superimposed Eye). (Hesse.)

The divisions I, II, III, of an object are arranged to correspond to the facetted members 1, 2, 3, corresponding to the field of vision in each case.

lide with objects in their path. Plateau, who made experiments with some 36 varieties of insects, found that when introduced into a sort of labyrinth provided with small enclosed spaces, they did not move about or escape without running into obstacles. They also walked or flew around corners with difficulty. On the other hand, such vertebrates as Rabbits, Guinea Pigs and various reptiles, under the same

conditions, escaped from the labyrinth without falling into the errors made by the insects in question.

Eyes of crabs. In some instances one finds either the (frontal, cyclopean) Nauplius eye, placed above in the middle line of the head in the shape of one single or a group of eye spots (Punctaugen); or as a pair of relatively large, compound eyes on the side of the head, mounted on movable (occasionally fixed) eye stalks. In some Crabs both lateral and single frontal eyes are present; in others, only the central ocelli; still other Crabs are provided with lateral eyes only.

EYES OF INSECTS

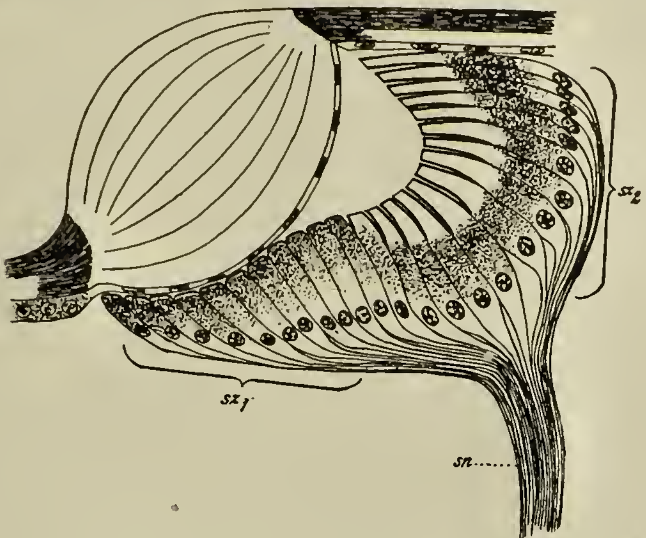
The eyes of some *Insecta* have been considered under Arthropods; it will be sufficient to say at this juncture that they are mostly bilateral, compound eyes, i. e., are composed of a large number of minute eyelets, each, as a rule, having hexagonal facets set in the surface of the head. These facets number from 20 to several thousand in each composite eye. In some insects these eyes make up almost the entire mass of the head. Their outline is generally spherical, but sometimes kidney-shaped. Rarely, these facetted eyes are composed of a group of ocelli (Punctaugen), or by single, bilateral eyes as in Fleas and Lice.

In Crabs, one finds not infrequently punctate eyes, one to three in number, placed in the median line of the head.

Speaking of the large, compound eyes of Hymenoptera, Parker and Haswell (*Text-Book of Zoology,* Vol. I, p. 644) remark that they, as in the case of the Crayfish, are divided into a great number of minute hexagonal facets, each of which represents one of the elements (ommatidia) that compose the visual organ. "When the eye is examined in section, each *ommatidium* is found to consist of a cornea-lens—the outer surface of which forms the facet—a crystalline cone, and a rhabdome. The crystalline cone is not always developed, its place being taken in the eyes of some Insects by four crystal cells. The rhabdome is an elongated rod. Beneath the rhabdomes is a fenestrated membrane, beneath which, again, is a dense plexus of nerve-fibres. Nerve-fibres pass through the fenestrated membrane and terminate in a delicate sheath which incloses each rhabdome, the sheath, together with the nerves that end in it, constituting the retinula. Pigment surrounds the crystalline cones and retinulæ.

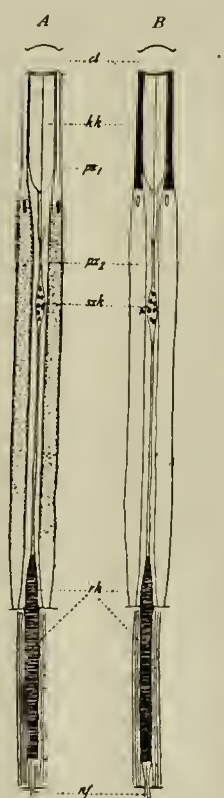
The ocelli, or simple eyes, consist of a bi-convex transparent thickening of the cuticle—the lens—and beneath it of a group of specially modified epidermal cells. Some of these, situated beneath the lens,

form a transparent mass, the vitreous body, another set of elongated cells being arranged to form the retina."



Frontal Ocellus of a Fly *(Helophilus sp.)*. (Hesse.)

sz_1, Visual cells with a short receiving segment, which lies close to the lens (thick contours); sz_2, visual cells, remote from the lens, with drawn out receiving segments; *sn*, optic nerve.



Two Facetted Members of the Facetted Eye of a Night Moth, Arranged for a Superimposed Picture. (Hesse.)

In *A* the pigment has the light position; in *B* the dark position; *cl*, cornea; *kk*, crystal cone; pz_1, main pigmented cells; pz_2, secondary pigmented cells; *rh*, rhabdome; *nf*, nerve ducts (nerve processes of the visual cells).

Lustre, Ocular. When one examines with a candle-flame the eye of a night Moth that has been living in darkness for some time previously, a reddish point of light appears on the corneal surface that has been compared to a coal of fire. This luminous area must not be confounded with the corneal reflex, because it is a reflection of intra-ocular origin; indeed, it may be obscured by the presence of the corneal reflex and for that reason rendered difficult of demonstration. This luminous point moves about with the movements of the candle-flame. After several exposures of the eye to the candle-light the lustre disappears, and will not be again observed until after another prolonged exposure to darkness.

This phenomenon which has been variously explained may be elicited in the vertebrate eyes by illuminating the pupil by means of a concave mirror provided with a strong convex lens. The condition has to do with variations in the amount of the retino-choroidal pigment.

It is faintly seen in (diurnal) Butterflies and not at all in the Coleoptera. It is wanting in Grasshoppers and Flies; in other words, in those insects whose eyes are but slightly pigmented. In Dragonflies (whose eyes are divided into two portions) the upper segment shows the ocular lustre very plainly; the lower part very feebly. It may also be noticed that when the illuminating point is moved to and fro in front of the insect's eye that the light-image moves rapidly in front of the upper half and slowly past the lower segment. Whence we may conclude that the dragon-fly uses the upper part for observing, or catching his prey, while the lower section is intended for close observation of fixed or slow-moving objects.

In Diptera, whose eyes are but slightly pigmented, the illumination is diffused.

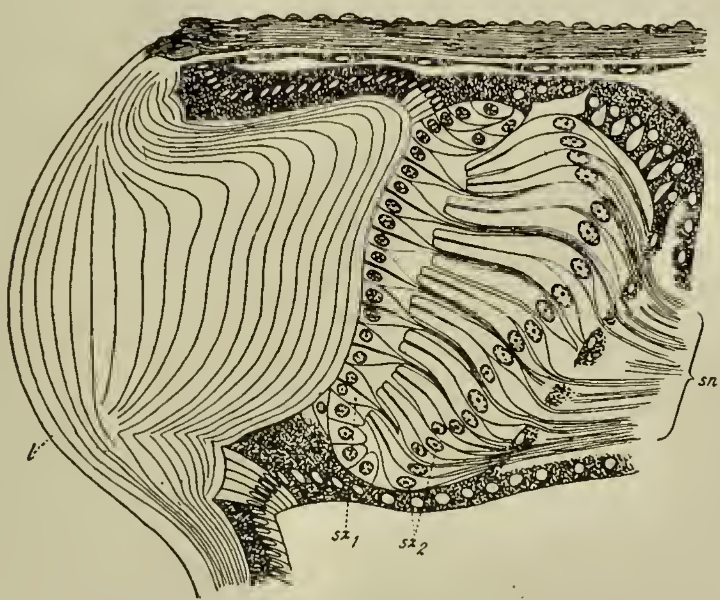
It must be remembered in this connection that many nocturnal, crustacean Decapods, especially after exposure for some time to darkness, exhibit a strongly marked ocular lustre.

False pupil. The pseudopupil of invertebrates has been especially studied by Leydig and Exner. If the corneal surface of an insect be examined by direct illumination a dark spot will be observed, which apparently corresponds to the pupil of vertebrates, but this spot moves about with the observer's eye, or as the illuminating source is moved. Moreover, other pseudopupils are to be seen arranged about the chief, central one.

False pupils are capable of development only in those eyes beneath whose cornea there is deposited a distinct layer of colored pigment. They are readily seen, for example, in the aquatic larvæ of *Agrion,* in day Butterflies, in Grasshoppers, in fresh-water Crabs, and Prawns,

but are developed with much difficulty in Sea Crabs, in Lobsters, and in those Coleoptera whose eyes show much pigment.

It is in the centre and field of the primary pseudopupil that the *ocular lustre,* elsewhere described in this section, is noticeable. M. E. Kalt (*Encyclopédie française d'Ophtal.,* Vol. II, p. 770) thus explains this phenomenon:—The eye of the observer who looks in the direction of an ommatidium (q. v.) receives an impression of color—the ocular lustre or sheen. As the axes of the neighboring ommatidia are not



Frontal Ocellus of a Dragon-fly *(Agrion sp.).* (Hesse.)
l, Lens; sz_1, sz_2, first and second row of visual cells; in them the light receiving elements (the rhabdomes) are represented by the thick lines; *sn*, optic nerve.

parallel the observing eyes receive only that portion of the emergent rays that are reflected by their pigmented walls, generally none; hence the black appearance of the pseudopupillary disc. The ommatidia farther away are seen still more obliquely, i. e., from a portion of the ommatidian tube lined with light-colored, pigment (i. e., blue, green) reflecting rays, of corresponding color which limits and defines the central black area or pupil.

EYES OF VERTEBRATES

Vertebrata include Fishes, Reptiles, Amphibia Birds and Mammals. They have an internal skeleton, a brain and vertebral column. This one sub-kingdom includes the most complex of animals, whose structure requires more minute examination than does that of the other sub-kingdoms.

Fishes and amphibia are generally united into one division, *Ichthy-*

opsida, as they agree in breathing by gills at some period in their life-history. Reptiles and birds are likewise united into a division,

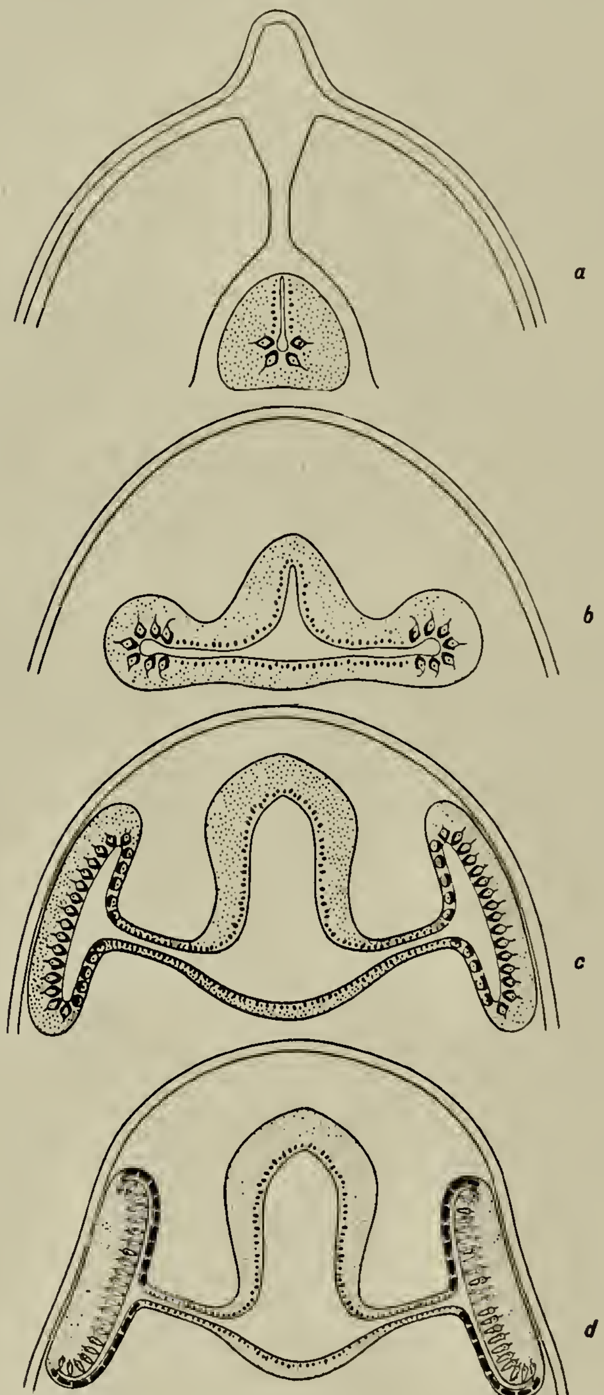
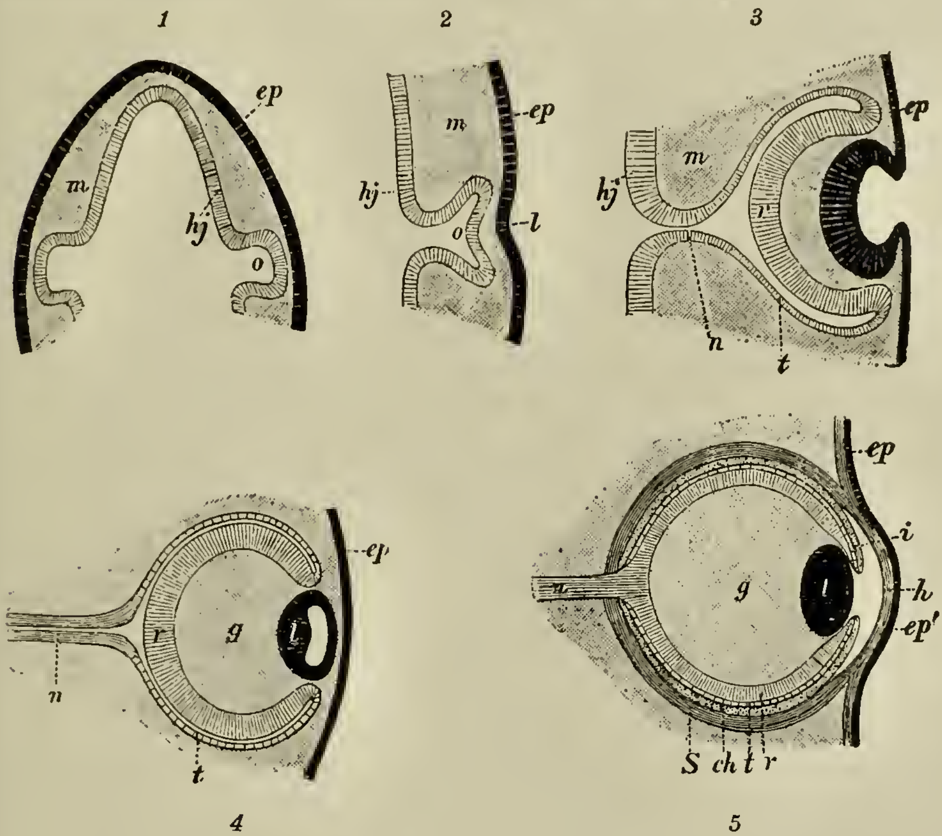


Diagram illustrating the Phylogeny of the paired Eyes of Mammalia in their Development from (a) the visual Organ of the lowest of the Vertebrates, viz.: *Amphioxus lanceolatus.* (Franz.) The dark spots are mostly pigment cells.

Sauropsida, as they agree in being oviparous, with large eggs containing much food-yolk, and never breathing by gills. Many fossil forms are

known which closely link the fishes to the amphibians and the birds to the reptiles.

Vertebrates are generally divided into *(a) Acrania* (headless) represented by one form only, *Amphioxus lanceolatus,* so called on account of its lancet-like shape. It is the smallest and simplest of the vertebrates, about a quarter of an inch long. A minute median, pigmented area at the front end is a rudimentary eye.



Development of the Vertebrate Eye. (Boas.)

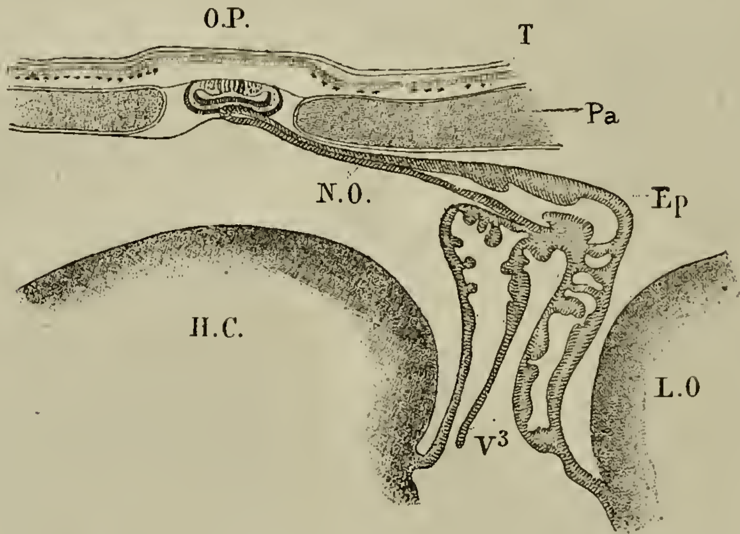
1. Section through the head at an early stage, the primitive optic vesicle having been formed. 2. Later; the first appearance of the lens. 3-4. Still further development of the eye: the lens is isolated; formation of the secondary optic vesicle. 5. The other ocular organs are developed. *ch*, choroid; *ep*, epithelium; ep_1, epithelium of the cornea; *g*, vitreous; *h*, cornea; *hj*, brain; *i*, iris; *l*, lens; *m*, mesoderm; *n*, optic nerve; *o*, primitive optic vesicle; *r*, retina; *S*, sclera; *t*, pigment layer of the retina.

All vertebrates have an even number of *(paired)* eyes; some are provided in addition with a *single* or *pineal eye.*

Ocular embryology of vertebrates. All the visual organs, paired or single, are developed from the midbrain or *thalamencephalon.* The anterior end of the neural tube of the embryo emerges very early in fetal life in the shape of vesicles called the *anterior, middle,* and *posterior primitive cerebral vesicles.* The cavity of these vesicles

corresponds to the future ventricles and are continuous with the central canal of the spinal cord. Eventually, the number of the vesicles is increased to five by division of the anterior and posterior primitive vesicles; so that we have the *prosencephalon,* the *thalamencephalon,* the *mesencephalon,* the *metencephalon,* and the *myelencephalon.*

From the thalamencephalon *(intermediate* or *mid-brain)* originate the *optic thalami* by general thickening of its lateral walls. From



Antero-Posterior Section of the Brain and Pineal Eye of (the Lizard) Varanus. (Baldwin-Spencer.)

LO, optic lobe; HC, cerebral hemisphere; V_3, third ventricle; *Ep,* epiphysis, with its trunk and optic nerve; OP, pineal eye.

its base arise two hollow prolongations that form the *primitive optic vesicles,* the retina and the optic nerves. Finally, from its superior aspect or roof is derived the *pineal gland* (epiphysis) and, from its inferior portion or floor, the *infundibulum* and a portion of the *pituitary gland,* or hypophysis.

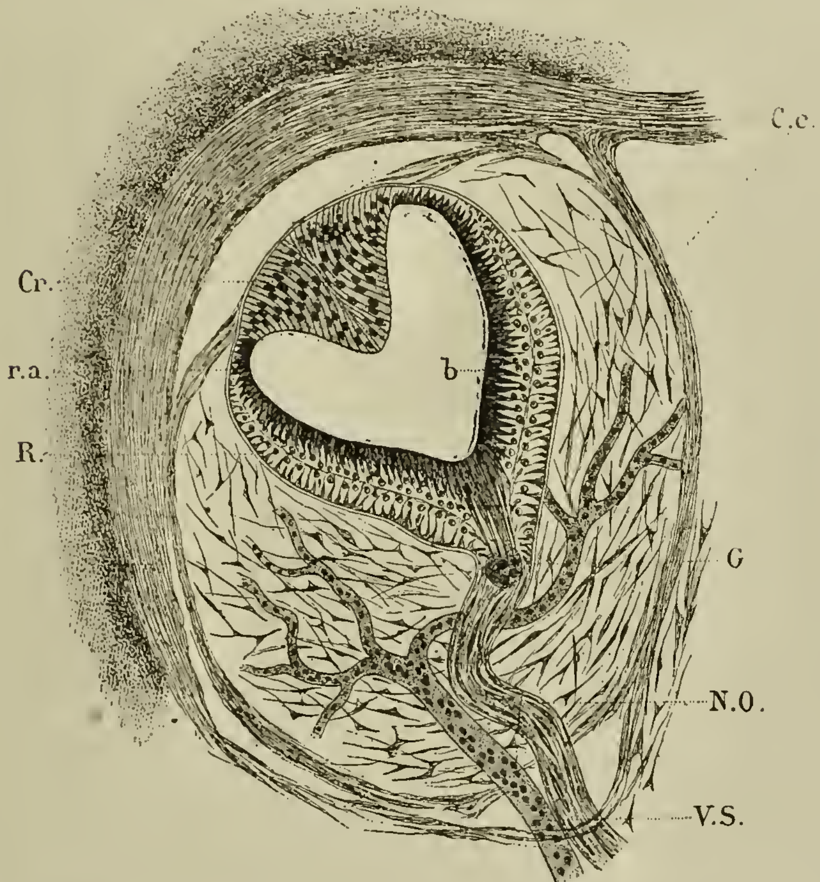
A more extended account of this subject will be found under the heading **Development of the eye,** as well as under the **Eyes of birds.**

The pineal eye. The pineal gland, the diverticulum of the anterior cerebral vesicle, is composed of a primitive pedicle (at first hollow, later becoming solid) and of a distal vesicle.

Leydig (*Die Arten der Saurier,* 1872) suggested the special sensory character of this section in the brain of the frog. He called it the *frontal organ.* Rabl-Rückhard (*Zoolog. Anzeiger,* June, 1886) described an epiphyseal organ in the osseous fishes. He also noticed that a similar organization is found in the embryos of certain reptiles and that the frontal bone is pierced at a corresponding point in the adult animal. This *parietal* canal is also seen in the fossil Saurians of the

lias, but the author thought it gave access to an organ whose function it was rather to register thermic changes than to act visually. Ahlborn (*Zeitschr. f. wissensch. Zoologie*, 1883), however, believed that considering its close embryological connection with the primitive optic vesicle that it represents the rudiments of a median or single eye.

Spencer (*Quarterly Jour.* New Series, 27, 1887) made extensive studies of the so-called pineal gland on a large number of Lizards and



The Pineal Eye of Hatteria punctata. Vertical antero-posterior section. (Baldwin-Spencer.)

Cr, Lens, developed from the anterior wall of the optic vesicle; R, retina developed from the posterior wall; *ra*, anterior portion of the retina continuous with the crystalline lens; *b*, retinal rods surrounded by pigment, situated on the anterior surface of the retina; N. O., optic nerve; C. c., conjunctival capsule representing the fibrous envelope of the eyeball; V. S., bloodvessel.

found in Hatteria an organization that closely resembles an eye. It exhibits a well-developed retina, although the other ocular organs are somewhat atrophied.

The *pineal eye of Hatteria* takes the form of a closed vesicle surrounded by a capsule of conjunctival tissue. This vesicle is situated below a point in the cranium corresponding to the parietal canal or foramen just referred to. The skin covering the opening is destitute

of pigment but quite opaque. The superior wall of the vesicle is thickened and forms a cellular lens; the posterior wall is the retina which is pierced in its central area by the optic nerve. The retina is composed of five layers; internally a layer of rods, whose surface is pigmented in the form of transverse striæ. The rods in the central retinal area are more than twice as long as the others, and are specially connected with a group of cells arranged at the entrance of the optic nerve.

Below this layer one sees two or three layers of spherical, nucleated elements; then comes a very thin, and finely punctate molecular layer followed by the most external layer exhibiting three different elementary bodies. This external layer receives the nerve fibres, which are provided with elongated nuclei similar to those one meets in the embryonic nerve tissues of lateral eyes.

According to Virchow (*Archiv. f. Anat. u. Physiol.,* 1901) this eye shows a minute fossa about 2 mm. from the optic papilla. There only cones are found like, for that matter, in the remainder of the retina.

The pineal eye of *Lacerta ocellata* is morphologically similar, except that some of the retinal cells have undergone degenerative changes into pigment cells. In *Varanus giganteus* pigmentary alterations are seen in the lens, while in other reptilian forms various signs of arrested development and secondary degeneration have been described.

In an embryo of the Slow-worm, Duval and M. E. Kalt (*Bulletin de la Soc. de Biologie,* Feb., 1889) proved the existence of several pineal eyes, while the latter demonstrated three separate eyes borne on the same epiphyseal trunk. The median eye was closely applied to the cranial wall and was by far the best developed.

The pineal gland is seen earliest in the Cyclostomes. It is but slightly developed in the Myxinoides but acquires a more definite structure in Petromyzon. Here it is a *double* organ, that is, two unequal eyes are found, the one placed above the other, the more voluminous and better developed one above, just beneath the skin.

In Selachii (Sharks, Rays), Ganoid fishes and tailless Batrachians, the parietal canal is closed during the embryonal period, although it is found intact in the Stegocephali, ancestors of the Batrachians. In the larval state of the latter amphibia the organ takes the form of a *creux* diverticulum, *renflé* at its extremity—somewhat like that found in the Chameleon. Later in the course of development the vesicle, separated from its pedicle, is represented by a mere pigmented patch on the surface of the skull. In many Fishes, in all the Urodeles, in a number of Reptiles, and in all the Birds and Mammalia the pineal eye has no direct connection with the dermal surface, nor is there an

opening in the cranium corresponding to it. In other words, the degradation of the organ is complete.

In conclusion, it may be said that with, perhaps, the exception of the lizard, *Lacerta ocellata,* no animal possesses a functionating, useful pineal eye. It was, indeed, in the pretertiary periods and in a number of (extinct) Saurians—Ichthyosaurus, Plesiosaurus, Iguandon (ancestors of present day Birds and Reptiles)—that the unpaired or pineal eye reached its highest development.

Unpaired eye of the Tunicata. The pineal eye of vertebrates seems to find a homologue in the unpaired eye of the Tunicata. The Ascidian eye disappears at the end of the larval period although it persists in some species. When it appears as the single form in the latter order it assumes the shape of a horseshoe.

The larvæ of Ascidians are also provided with an unpaired eye situated in the posterior wall of the cerebral vesicle. It consists chiefly of a retina formed of large prismatic cells, whose free extremities are pigmented, associated with a lenticular body set in a retinal cup.

This eye develops, like that of vertebrates, by invagination of the primitive ectodermal layer which provides for the nerve centres. The lens is a secondary formation.

Eye of Amphioxus. It was for a long time believed that a solitary pigmented spot, placed immediately in the anterior portion of this animal was an ocellus, without any other ocular differentiation. Hesse (*Zeitschr. f. wiss. Zoologie,* Vol. 63, 1898) has, however, shown that Amphioxus possesses numerous visual organs of characteristic structure. They consist of a double row of pigmented organs placed on the ventral aspect of the medullary canal. Each pigment spot surrounds two or more definite cellular elements.

The visual elements constitute unicellular ocelli and are almost identical with the visual organ in the *Planaires.*

They afford a varied orientation according to their position in the animal. The ocelli on the left half of the body are directed above and to the right; those on the right side are directed below and towards the right of the animal. Doubtless this disposition of the eye-spots is in strict accord with the habits of Amphioxus, about which little is known, except that its life is largely spent in semi-darkness—muddy water and sand—which requires a specially adapted visual organization.

Franz (*Lehrbuch der Vergl. Anatomie der Wirbelthiere,* 1913) believes that the anterior pigment spot which represents the principal organ of sight in Amphioxus is not the only organ of vision or, rather,

of light perception, and he discusses the dorsal pigment cells and the other "eyes" of the lancelot, and shows how the paired organs of the higher vertebrates are evolved out of the primitive visual cells of amphioxus.

While the vertebrate animal kingdom does form an irregular linear ascent from Amphioxus to Man, yet the ocular apparatus does not give decided evidence of this culmination. As Franz points out it is not the human eye but the bird's eye that stands highest in the scale, and between the so-called lowest and highest organism one finds animal eyes that seem to be out of all proportion to the development of the other parts of the organism. The human eye is not only inferior in many respects to even the poorest forms of the avian eye, but it probably ranks as low as the eye of the amphibians and fishes.

The bird's retina, if we are to judge by the number of light-percipient elements to the square millimetre, and by the sharp division of the layers of the retina, not to mention the exceedingly elaborate accommodative apparatus, is a much more highly developed and effective visual organ than that possessed by any race of men.

A comparison of the various organs of the visual apparatus in the class of vertebrates shows that the bird's eye is probably derived from the reptilian, or, rather, that birds and reptiles had a common ancestor. The descendants evolved a much more effective eye in the bird. This ancestor or ancestors have been grouped by zoologists under the common name of Sauropsida.

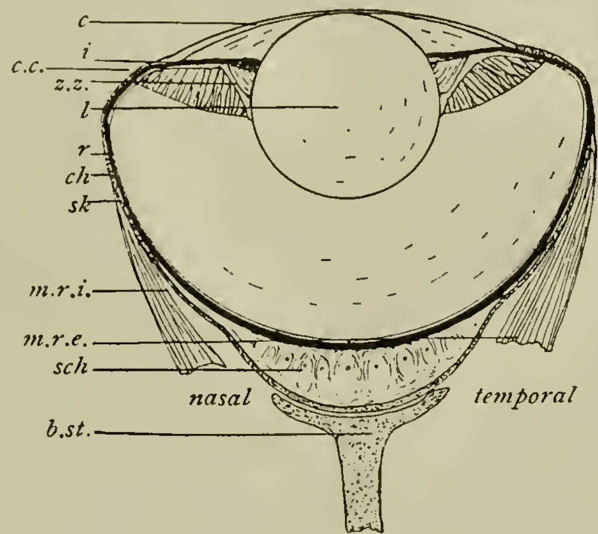
THE EYES OF THE FISHES.

Fishes are the simplest of the head-bearing (Craniota) vertebrates. They furnish about 13,000 species, generally divided into five orders. The latter include the *Marsipobranchii,* "pouch-like" gilled-fish—vermiform, limbless, scaleless fish—the lamprey and the hag; *Elasmobranchii*—sharks, rays, skates, dog-fishes; *Ganoidea*—the sturgeon, pike, pickerel; *Teleostei*—the largest group of fishes, with biconvex vertebral bodies. The six sub-orders or families into which this last-named order is divided, include the herring, gold-fish, eel, salmon, trout, and most of our fresh-water fish.

The eyeballs of fishes are rarely spherical, owing to their flattened cornea. There are no true, movable eyelids, but sometimes the eye is provided with fixed dermal folds, evidently the analogues of lids. In the Mackerel and the Herring a transparent membrane partially surrounds the eye, while in some Sharks there is a well-defined, movable, nictitating membrane drawn over the cornea, as in Birds, by adductor

muscles. The sclera is well developed; externally it is formed of fibrous tissue, internally a cartilaginous layer, which, as in the Sturgeon, is sometimes very thick. In the Bony Fishes this layer of cartilage is further stiffened at the corneal border by two osseous plates. In some cases these plates, as in Birds, form a complete ring about the cornea. The piscian choroid is composed of several layers; externally one notices the silvery sheen of the *tunica argentea,* a thin areolar tissue layer studded with crystals. In some Sharks and the cartilaginous Ganoids there is a true, light-reflecting *tapetum.*

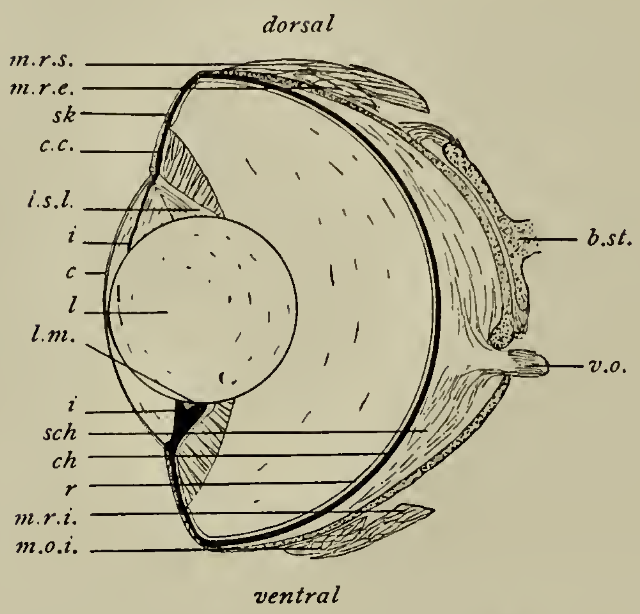
In some Osseous Fishes is found the so-called *choroid gland,* a large, horseshoe-shaped organ placed in the neighborhood of the optic nerve. These animals also exhibit the *processus falciformis,* sometimes described as a fold of the choroid, the analogue of the pecten in Birds and



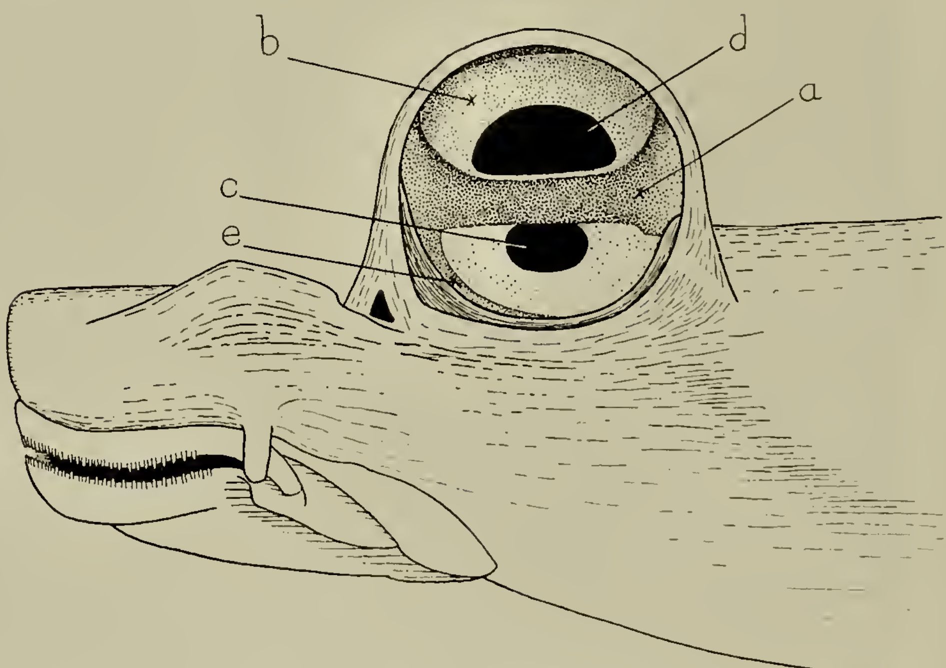
Horizontal Section of the Eye of (the Fish) *Acanthias vulgaris.*
c. Cornea; *i,* iris; *cc,* ciliary body; *zz,* zonula; *l,* lens; *r,* retina; *ch,* choroid; *sk,* sclera; *mri,* internal rectus muscle; *mrc,* external rectus muscle; *sch,* suprachoroidea; *bst,* ocular pad or support.

attached, like it, within the eyeball along the optic nerve entrance. It is, as shown elsewhere, undoubtedly an essential part of the accommodative apparatus.

The eye of the Brown Trout *(Salmo fario)* furnishes a good idea of the ocular apparatus of the Bony Fishes. The histology is given in detail by Parker and Haswell, as follows: "There is a very flat cornea (*m*) with which the globular *lens* (*l*) is almost in contact, so that the aqueous chamber of the eye is extremely small. Between the cartilaginous sclerotic (*a*) and the vascular choroid (i) is a silvery layer or argentea (g) which owes its color to minute crystals in the cells of which it is composed. In the posterior part of the eye, between the choroid and the argentea, is a thickened ring-shaped structure (f)



Vertical Section of the Eye of (the Fish) *Acanthias vulgaris*. Except *moi*, inferior oblique muscle, the references are the same as in the preceding Figure. (Franz.)

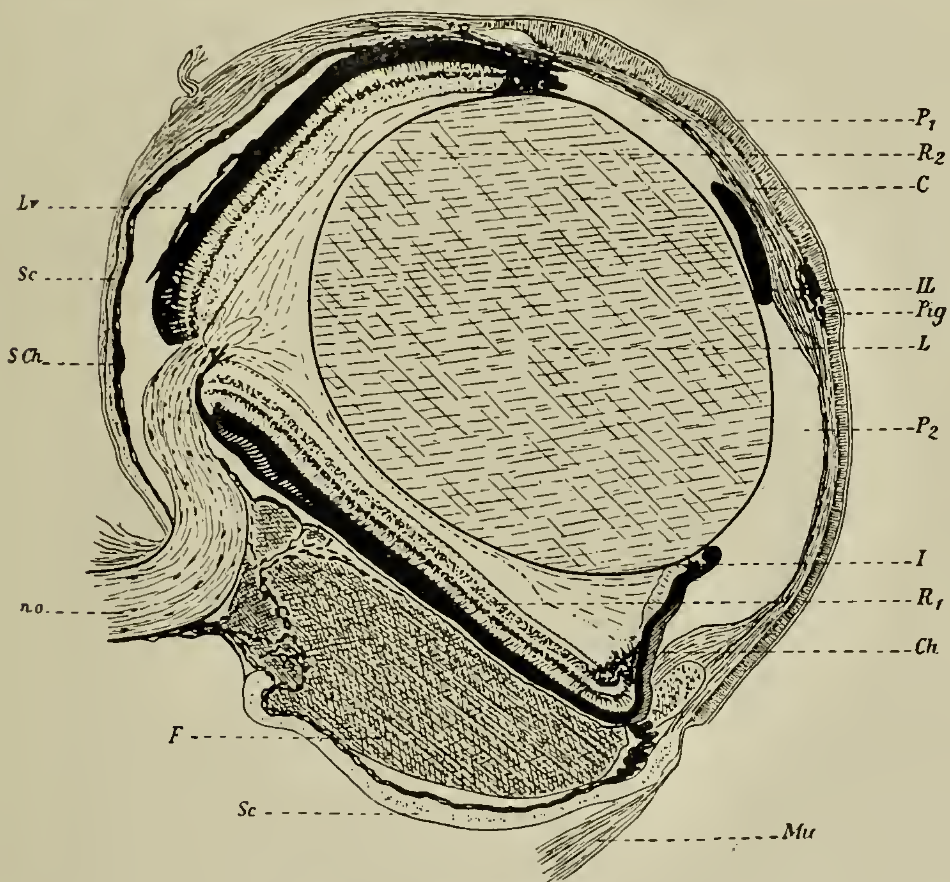


Left Side of Head and Duplex Eye of the South American Fish, *Anableps anableps*. Natural size. (Original.)

a, Pigmented corneal band; *b*, cornea, beneath which is the iris; *c*, inferior pupil for subaqueous use; *d*, superior or aerial pupil; *e*, circumcorneal band of pigment. The eye is elevated more than one-half its height (radius) above the dorsum.

surrounding the optic nerve, and called the choroid gland: it is not glandular, but is a complex network of blood-vessels, or rete mirabile. It is supplied with blood by the efferent artery of the pseudobranch.

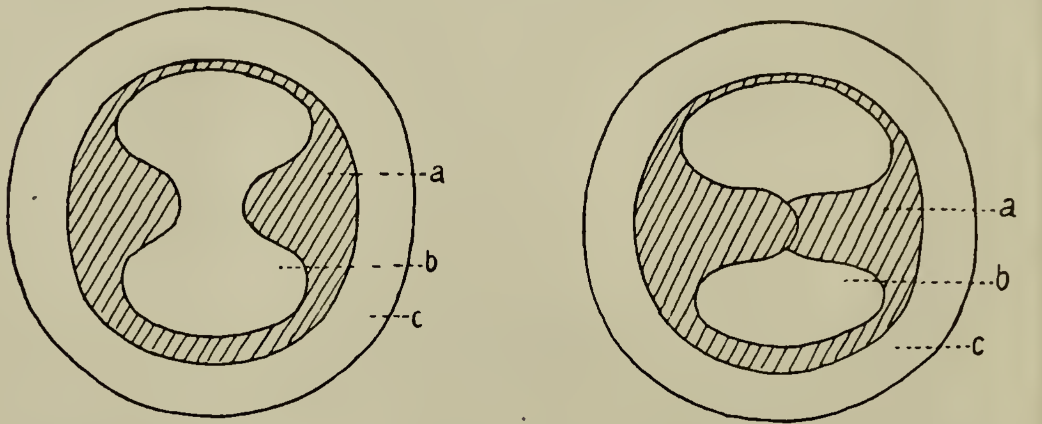
Close to the entrance of the optic nerve a vascular fold of the choroid, the falciform process (c) pierces the retina, and is continued to the back of the lens where it ends a knob, the campanula Halleri (b) which contains smooth muscular fibres. The falciform process with the campanula Halleri take an important part in the process of accommodation by which the eye becomes adapted to forming and receiving images of objects at various distances. Accommodation in the Fish is effected, not by an alteration in the curvature of the lens as in higher vertebrates, but by changes in its position, by which it becomes more approximated towards, or further withdrawn from, the retina. In bringing about these changes of position, the structures in question appear to play the principal part."



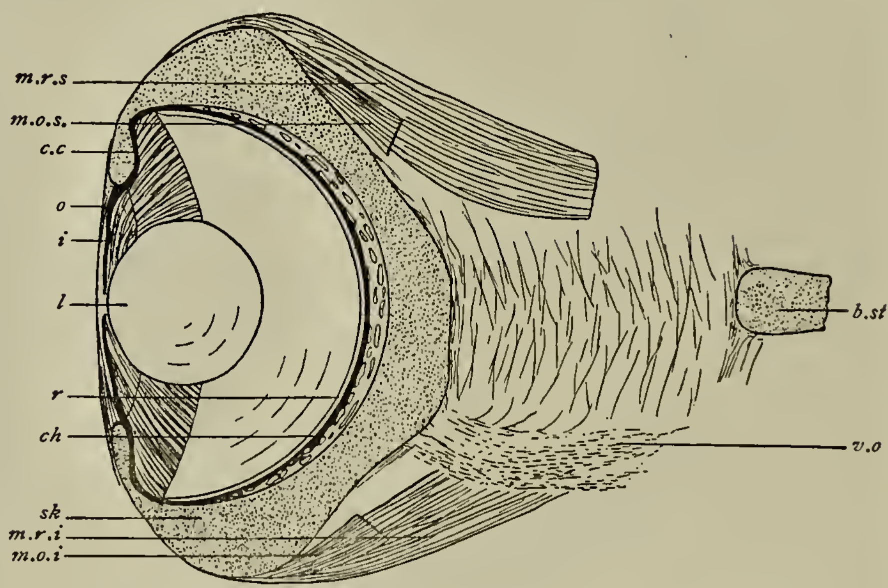
Section of the Eye of *Anableps tetrophthalmus* (Four-eyed fish). (Franz.)

The *Flat Fishes* have eyes worthy of note. They rest their flat and wide bodies on the sea bottom, some species on the right, some on the left side, partially covered with sand. In this situation they swim with an undulating movement. The under aspect is very white; the upper dark brown or almost black. The eyes are found on the upper, dark-colored side set in orbits, one of which has been apparently dis-

placed medialwards. Newly born Flat Fishes swim in the usual vertical position and have symmetrically placed eyes, but as they grow older they choose one of their two sides to be uppermost during future locomotion. Then a curious ocular change occurs—to correspond with



Two Stages of Contraction of the Pupil of *Anableps tetrophthalmus* (Four-eyed fish). (From Franz.)



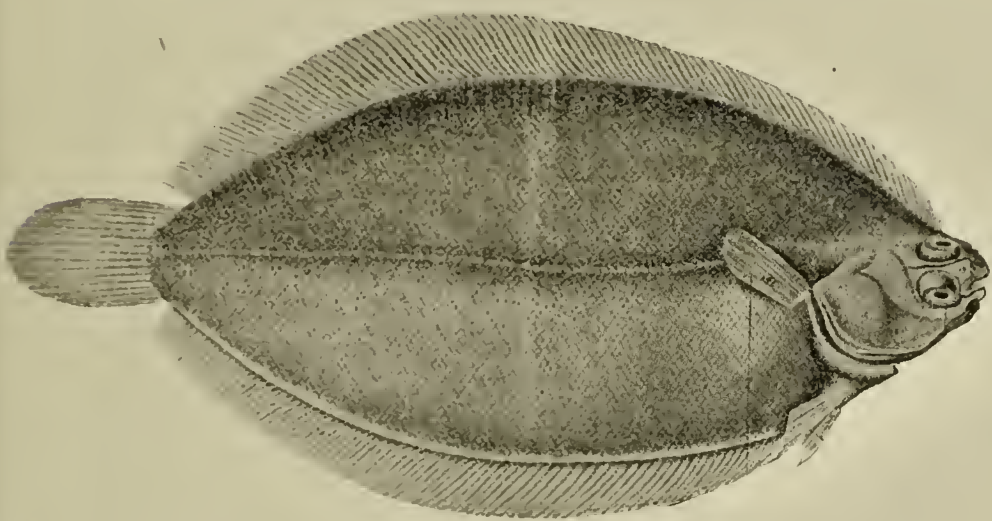
Section of Eye of *Selache maxima* (Basking shark). (Franz.)
mrs, Rectus superior muscle; *mos,* superior oblique muscle; *cc,* ciliary body; *o,* cornea; *i,* iris; *l,* lens; *r,* retina; *ch,* choroid; *sk,* sclera, with plates of cartilage; *m. r. i.* rectus inferior muscle; *moi,* inferior oblique muscle; *vo,* optic nerve sheath; *bst,* optic pad.

the alteration in the swimming habit—the eye on the lower side gradually rotates, until it assumes the position depicted in the illustration.

The *eye of Sharks and Rays* has, as in Birds, a cartilaginous sclera, generally attached to the inner orbital wall by means of a stout, cartilaginous stalk. Some Sharks exhibit a conjunctival fold that resembles the partially developed nictitating membrane of mammals

Accessory eyes and other eye-like structures of Fishes. Leuckart has described, under the name *accessory eyes,* curious cylindrical organs found in large numbers in Chauliodus and Stomias, Fishes of the Scopeloid group.

The interior of the cylinder includes anteriorly a crystalline mass from which projects (behind) a conical prolongation that incloses what might be a vitreous body. The whole is in a fibrous envelope whose continuity is broken in front by a well-defined crystalline lens. The internal surface of this envelope is covered by a pigment layer whose brilliant appearance recalls the tapetum of the Plagiostomes. Posteriorly is attached a nerve filament whose final destination is unknown.



Eyes of the Craig-fluke, *Pleuronectes cynoglossus.* Seen from the Right Side. (After Cuvier.)

Although this organ resembles an eye, yet Leuckart throws doubts on its ocular character. He affirms that several other Fishes, closely related to those under discussion, exhibit similar organs in corresponding positions that quite evidently play the part of a reflecting apparatus only.

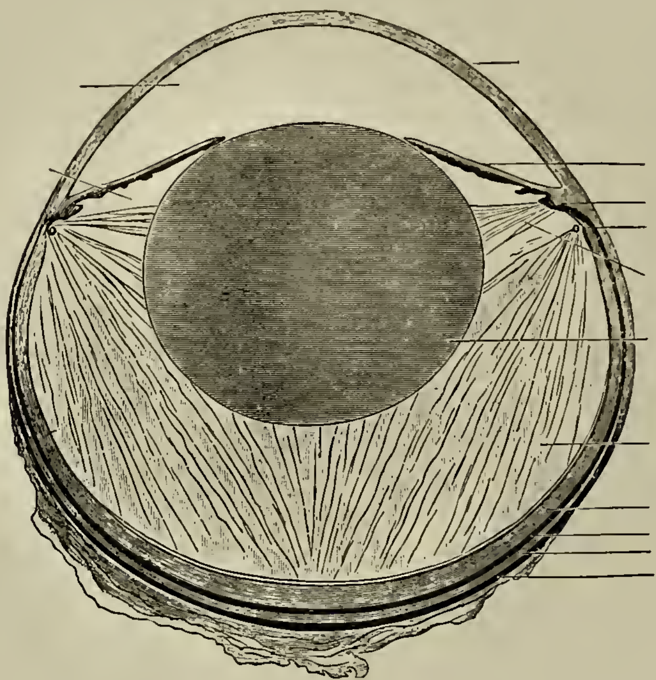
Ussow and Leydig have both investigated this subject and distinguish two varieties of these "accessory" organs, one class that are probably genuine eyes and a second that are nothing but pigmented glands.

In the Stomias Ussow found in the depths of the eye a true retina provided with rods and probably connected with nerve filaments.

Leydig believes all these (accessory) organs to be piscine reflectors —mostly phosphorescent and, possibly, electric.

EYES OF AMPHIBIA.

As the various ocular organs of Amphibia will be considered seriatim with the corresponding organs of other vertebrates, little will be said about them here. These curious land-and-water animals possess organs adapted to both subaqueous and terrestrial life and the eye is no exception to that rule. The eye is degenerate in most cave forms and eyelids are wanting in the lower forms generally.



Meridional Section of the Eye of an Amphibian (Frog). (Franz.)

In this connection Uhlenhuth (*Archiv. f. vergleich Ophthalm.*, p. 290, 1913) deals with the *transplantation of the eye* of a young salamander larva into the socket of an older animal. Not only did the transplanted eye continue to grow, but it passed through the various stages of metamorphosis followed by the other eye, except that the transplanted eye developed earlier than the remaining organ. The metamorphosis of the transplanted eye progressed simultaneously with the fellow eye of the host, thus giving evidence of synchronism of metamorphosis. The modification of growth and development showed, however, in the deposition of the iris pigment of the transplanted eye. It was discovered not in the proper place but throughout the whole organism.

The process reaches its height in about six or seven days, and is then followed by regeneration. This takes place chiefly from the pars ciliaris retinæ, the nuclei of which become enlarged and show active karyokinesis. The new cells travel backwards, taking the place of the degenerated retinal elements, and so form a new, but undifferentiated.

retina. Two layers of cells now become distinguishable, from the inner of which the ganglion cell layer takes origin, while the outer again divides to form the inner and outer nuclear layers. From the latter the rods and cones sprout, and the differentiation of the retina is completed by the formation of a nerve fibre layer. If the degeneration of the outer layers has not been complete, they also share in the regeneration. The process is much quicker in summer. It is less complete in the frog than in the triton, differentiation usually remaining imperfect.

EYES OF REPTILES.

The first order is *Lacertilia,* Lizards, including the Gecko, the Chameleons and the South American Iguanas. They are scale-clad, and at least forelimb-bearing reptiles, with a heart possessing a single ventricle, and with a lower jaw of firmly united segments. The *eyes* are provided with movable and functional eyelids, and the teeth are not in sockets, but are disposed in rows either around the edge or along the side of the jaws.

Order 2, *Ophidia,* or Snakes, includes boas, pythons, adders, cobras and similar animals, both harmless and poisonous. The eyelids are confluent and transparent, forming the clear glassy surface of the eye, and thus giving to the serpents the stony, unwinking stare peculiar to them.

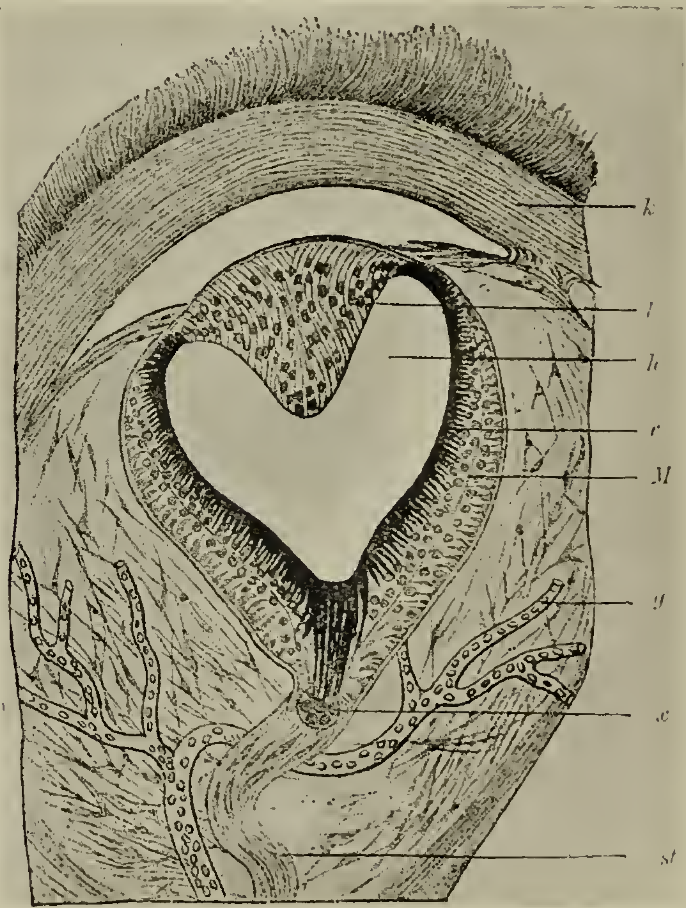
Order 3 comprises *Chelonia,* the turtles and tortoises. These reptiles are enclosed in a bony case composed of a dorsal or upper convex shield, called the carapace and a flat ventral or under shield, the plastron.

Order 4, *Crocodilia,* is the highest in organization of the entire class. They are inhabitants of the rivers of tropical countries, and are among the largest of living reptiles.

The average eye of Reptiles closely resembles, morphologically, the same organ of Birds. For instance, it has a cartilaginous layer with anterior bony plates in the sclerotic; also a vascular, pigmented *pecten* projecting well into the vitreous. It is furnished both with lachrymal and Harderian glands; the muscular fibrès of the iris are striated, and there are two well-developed eyelids and a functionating, nictitating membrane. However, in many of the Geckos the third lid passes over the cornea in winking, but there is a transparent area in the nictitating membrane (in correspondence with the pupil-cornea area) to admit light. In Snakes this arrangement seems to be permanent, the membrane being immovable and fixed upon the cornea. Chameleons have but one lid with a central opening opposite the pupil.

The *median or pineal eye,* as previously stated, is best represented in certain Lizards. Parker and Haswell point out that it is sometimes formed from the distal end of the epiphyseal diverticulum. It takes

The Osseous Plates in the Sclerotic of Lizards. (After Wiedersheim.)

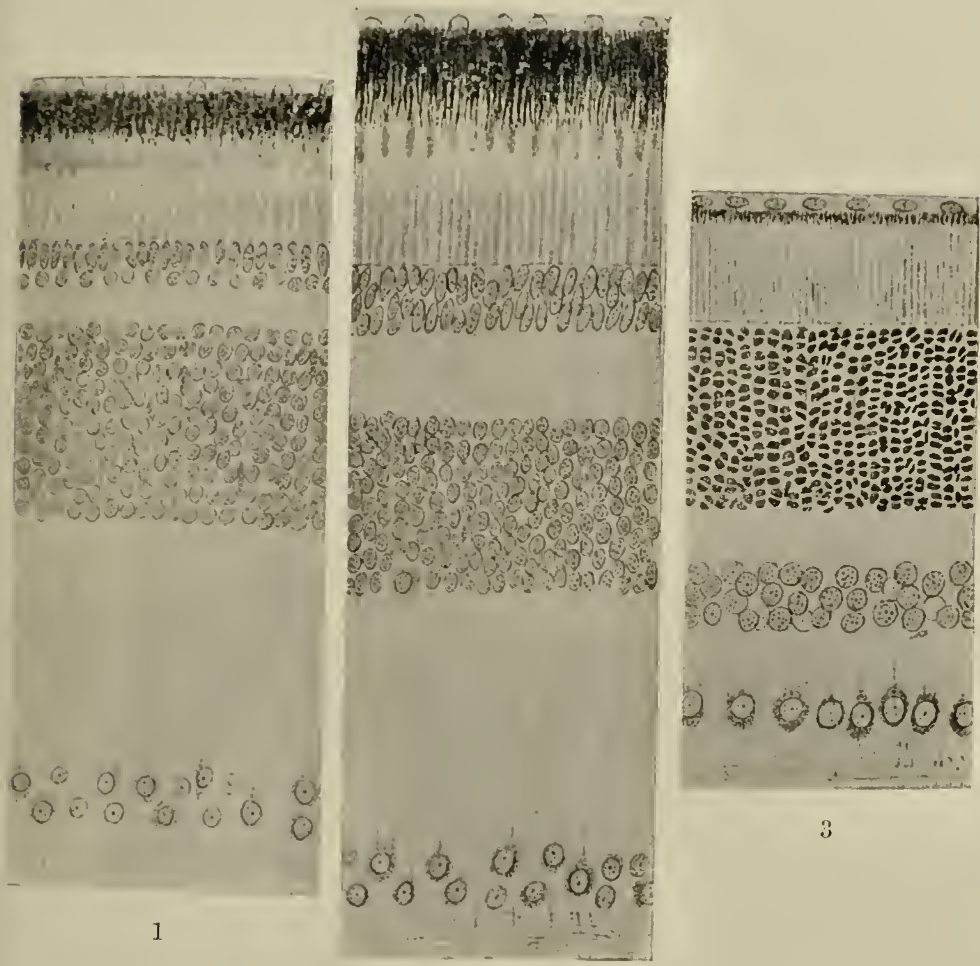


Section of the Pineal or Median Eye of the Lizard-like Reptile Hatteria, or Sphenodon. (Wiedersheim.)

st, Optic nerve; *x,* nerve cells; *g,* bloodvessel; M, retinal molecular layer; O, rods and cones; *h* (vitreous) cavity filled with fluid; *l,* lens; *k,* connective tissue capsule.

the form of a rounded capsule, the outer or anterior portion of the wall of which is a lens (see the cut) formed of elongated cells, while its posterior part is retinal. The retina has an outer layer of nerve

fibres and an inner collection of rod-like visual elements, thus giving the picture of the invertebrate eye.



1 2 3

Sections of the Retina of (Fig. 1) a Lizard; (Fig. 2) Crow; and (Fig. 3) Dog. (Chiarini.) x 510.

THE EYES OF BIRDS.

These animals are of extreme interest to the student of comparative ophthalmology because in them the visual apparatus reaches its highest development. These familiar animals possess an epidermal clothing of feathers, warm blood, a four-chambered heart, no teeth, and in general an adaptation for aerial locomotion.

About 12,000 species of birds are known to the naturalist, and these are *divided into two primary sub-classes.*

The first sub-class is called Ratitæ, and includes all those birds which have a sternum without a keel. This sub-class includes the Ostriches, the Cassowary, a native of the East Indian archipelago, and the Emu

of the Australian continent. The apteryx of New Zealand is the most remarkable of these birds, as it has perfectly rudimentary wings and a long slender bill, and there is a remarkable disproportion between the size of the egg, which is very large, and that of the bird.

The second sub-class of birds is called Carinatæ and includes all those birds which have a keel on the breast-bone. This includes, according to some authorities, fourteen orders of birds.

Order 1, Parrots (Psittaci).—These are the most intelligent and most highly organized of birds. They include the Cockatoos, the Macaws from South America, and the Parrots.

Order 2, Cuckoos (Coccygomorphæ).—Other examples of this order are the Kingfishers, Bee-eaters, Hoopoe, Rollers, etc.

Order 3, Woodpeckers (Pici).

Order 4, Swifts and Humming-Birds (Macrochires).—A small order of birds, mostly of very minute size, and almost all of powerful flight. They include, also, the Goatsuckers or Night Hawks.

Order 5, Perching birds (Passeres).—This very large order includes all our small birds, with the exception of those hitherto mentioned, such as the Sparrows, Thrushes (Blackbird, Mocking Bird, Warblers), Crow, Finches, Larks, Buntings, Nuthatches, etc., Wagtails, Raven, etc.

Order 6, Birds of Prey (Raptores).—This order consists of Eagles, Owls, Hawks and Vultures.

Order 7, Pigeons (Gyrantes).—This well-marked group consists of the Doves and Pigeons.

Order 8, Scraping birds (Rasores).—This large and economically important order includes the poultry, Turkeys, Pheasants, Grouse and Partridge.

Order 9, Grallæ.—This group consists of long-legged birds, the Plovers and Peewits, Coots and Waterhens, Corncrakes and Snipe, the Cranes and Bustards, Oyster-catchers, Herons, and Bitterns.

Order 10, Storks (Ciconiæ).—This group also consists of birds with long legs and bills. The best known examples are the Ibis, Spoonbill, stork and jabirus.

Order 11, Ducks and Geese (Lamellirostres).—The best known forms are the Ducks, Geese, Mergansers, Swans, Teals, Widgeon, etc.

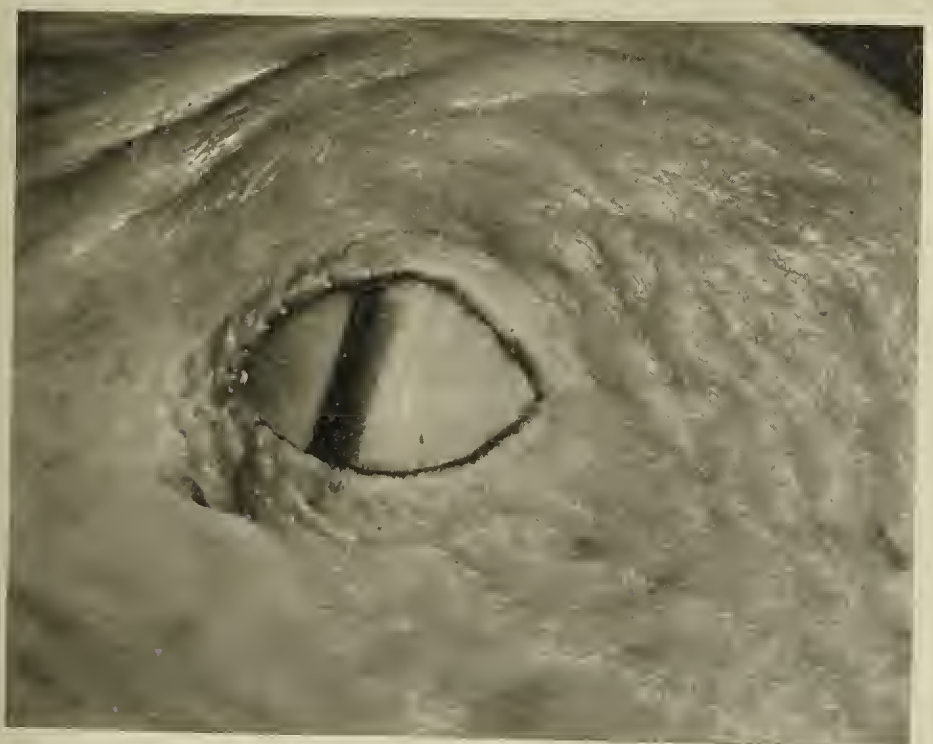
Order 12, Longipennes.—These are web-footed marine fish-eating birds, with long pointed wings well fitted for flight.

The Gulls, Terns and Petrels are the best known examples, the largest species in the order being the famous Albatross.

Order 13, Pelicans (Steganopodes).—A curious order of water birds. Many of them have long bills and throat pouches, like the

Pelicans and Frigate birds; other and better known forms are the Gannets, Cormorants, and long-tailed tropic birds.

External Eye of the Lesser Snow Goose—*Chen hyperboreus.* (Wood and Slonaker.)



External Eye of the Lesser Snow Goose—*Chen hyperboreus.* x 3. (Wood and Slonaker.)

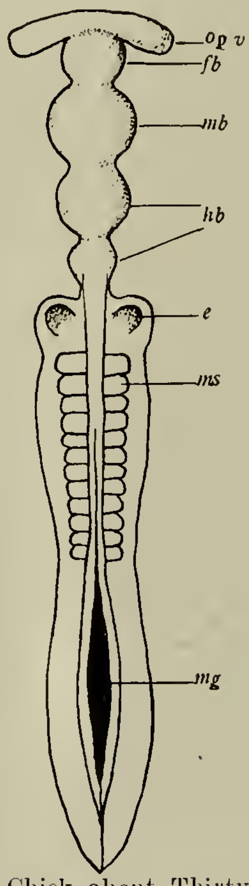
Order 14, Pygopodes.—The last order of birds includes Penguins, Auks, Puffins, Guillemots and Razorbills.

An introductory, elementary section on **Birds, Eyes of** will be found

on page 979, Vol. II of this *Encyclopedia,* and to it the reader is referred with the advice to read it at this juncture.

Embryology of the bird's eye. Before taking up this subject further the development of the different structures of the avian eye from the earliest age available to the adult in some one bird not hitherto described is here presented.

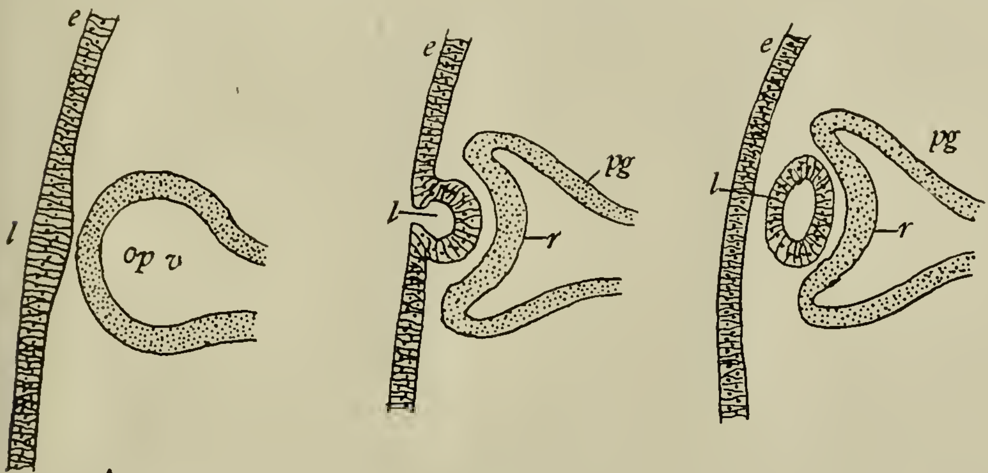
The English Sparrow *(Passer domesticus)* has been chosen for this purpose because of its abundance and the ease with which the early stages may be obtained.



Dorsal View of the Embryo Chick about Thirty Hours. (Wood and Slonaker.) *e,* Auditory pit; *fb,* fore-brain; *hb,* hind-brain; *mb,* mid-brain; *mg,* medullary groove; *ms,* mesoblastic somites; *op v,* optic vesicle.

So far as we know, the development of the different structures of the eye in all birds follows the same general plan. The only difference which obtains is the interval in point of time that intervenes in the appearance of these parts. Since the period of incubation varies somewhat between 12 and 48 days in different species of birds, the first *Anlage* of the lids, nictitating membrane, etc., would be seen at an earlier age in a bird whose incubation period is 12 days than in one with a longer period. But the relative order of development is the same in all species.

The period of the incubation of the English sparrow varies slightly between 12 and 13 days depending on the weather, the location of the nest, and the amount of time the bird is on the nest. Warm weather and a sheltered or protected nest tend to shorten the period of incubation. Owing to the fact that it is difficult to ascertain definitely when the eggs are laid and just how much incubation occurs in the first eggs laid at each subsequent laying period, it is well nigh impossible to determine accurately the exact age of the embryos taken. We have given in the following description the approximate age as nearly as it could be determined.



A B C

Diagrams Showing the Development of the Lens and Optic Cup. (Wood and Slonaker.)

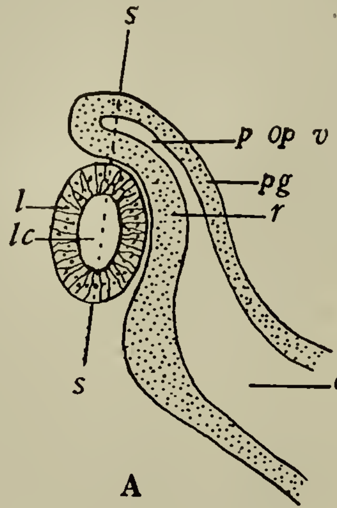
e, Epithelium; *l*, lens; *op v*, optic vesicle; *pg*, posterior and *r*, anterior wall of the primary optic vesicle.

We were not successful in securing the earliest stages of the sparrow representing the development of the primary vesicles of the brain and the formation of the optic vesicle. In order to make the developmental steps complete we have substituted these stages in the chick. Since the development of all birds' eyes follow the same relative plan this substitution may, perhaps, be allowable, especially as the only embryological difference is the relatively earlier age at which these stages appear in the sparrow embryo.

As is well known, the development of the eyes in all vertebrates follows the same general plan. They first appear as lateral projections from the fore-brain known as the *primary optic vesicles.* These projections grow laterally until they come in contact with the *epiblast,* whose cells at this point become elongated and foreshadow the beginning of the lens.

A photograph of a cross-section of a chick embryo about 40 hours old—shows the two optic vesicles projecting laterally and downward

from the brain cavity. The right vesicle shows a noticeable thickening of the external portion of the vesicular wall and the adjacent epiblast. The epiblast now begins to show an excavation from the outside at the



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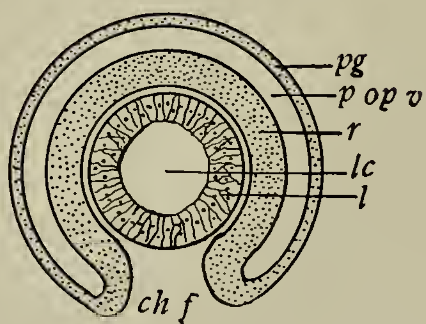

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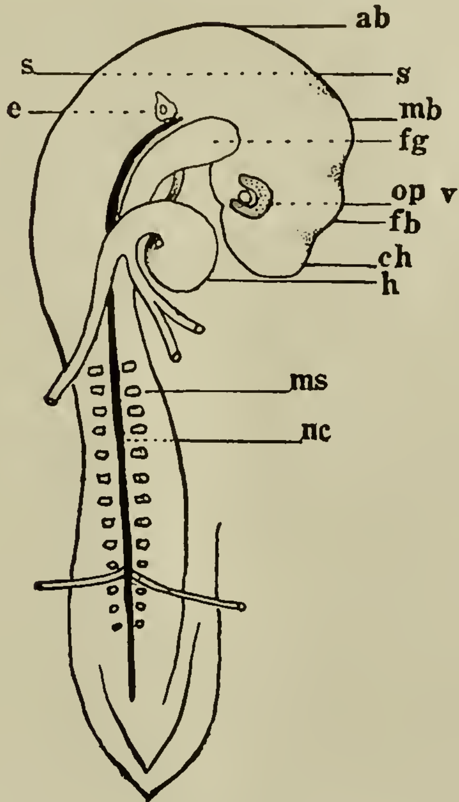
A, Diagram of a Vertical Section of the Eye of the Chick at about Forty-four Hours in the Plane S-S of next Fig.

B, Diagram of a Section made Vertical to A, along the Line S-S. (Wood and Slonaker.)

ch f, Choroid fissure; *l*, lens; *lc*, lens capsule; *op st*, optic stalk, *pg*, posterior wall of the primary optic vesicle; *p op v*, which later becomes the pigment layer of the retina; *r*, anterior layer which forms the retina.

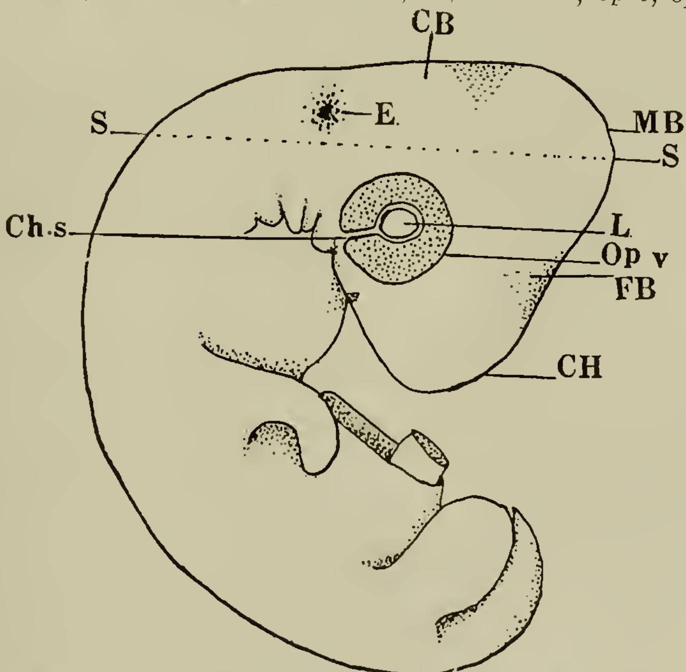
same time pushing before it the outer wall of the optic vesicle, thus forming the double-walled *optic cup* or *secondary optic vesicle*. This stage is reached in the chick at about the fiftieth hour of incubation.

A section through the head of a chick of 56 hours' incubation shows invagination of the epiblast and the formation of the optic cup is very



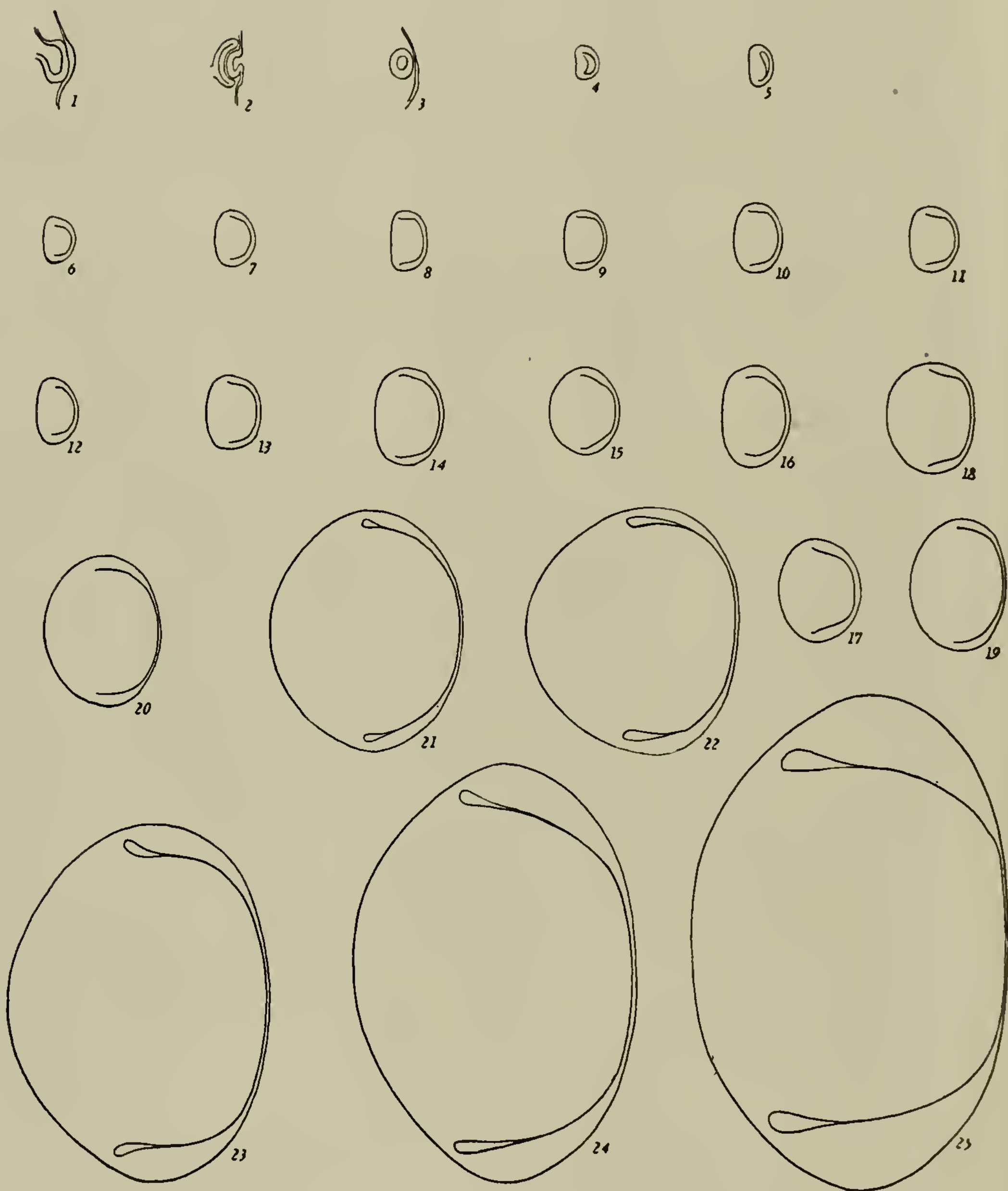
The Chick of about Forty-four Hours, Showing Side View of the Head. (Wood and Slonaker.)

ab, After-brain; *ch*, cerebral hemispheres; *e*, odic vesicle; *fb*, fore-brain; *fg*, fore-gut; *h*, heart; *ms*, semoblastic somites; *nc*, notocord; *op v*, optic vesicle.



Side View of the Chick about Ninety-six Hours. (Wood and Slonaker.)

CB, Cerebellum; CH, cerebral hemispheres; Ch s, choroid slit; E, ear pit; FB, fore-brain; L, lens; MB, mid-brain; Op v, optic vesicle; S-S, plane of section in second preceding figure.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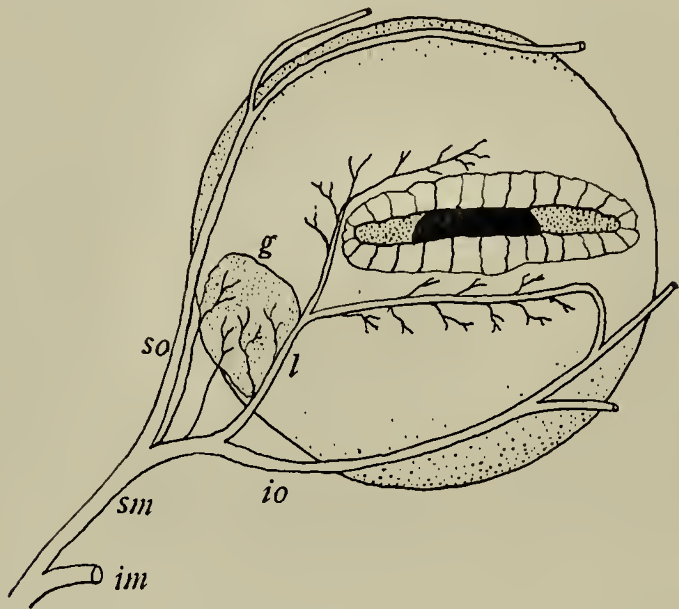
Figures of Lens Development to Show the Development of the Posterior Lens Cells, the Thinning Out of the Anterior Layer and the Development of the Annular Pad of the Lens from the Early Stages to the Adult. (Wood and Slonaker.)

Fig. 1. Chick, 40-48 hours' incubation.
Fig. 2. Chick, 56 hours' incubation.
Fig. 3. Chick, 64 hours' incubation.
Fig. 4. Chick, 68 hours' incubation.
Fig. 5. Chick, 90-100 hours' incubation.
Fig. 6. English Sparrow, 2 days' incubation.
Fig. 7. English Sparrow, 2½ days' incubation.
Fig. 8. English Sparrow, 3 days' incubation.
Fig. 9. English Sparrow, 4 days' incubation.
Fig. 10. English Sparrow, 5 days' incubation.
Fig. 11. English Sparrow, 6 days' incubation.
Fig. 12. English Sparrow, 7 days' incubation.
Fig. 13. English Sparrow, 7¼ days' incubation.
Fig. 14. English Sparrow, 7¾ days' incubation.
Fig. 15. English Sparrow, 8 days' incubation.
Fig. 16. English Sparrow, 9 days' incubation.
Fig. 17. English Sparrow, 10 days' incubation.
Fig. 18. English Sparrow, 11 days' incubation.
Fig. 19. English Sparrow, 12 days' incubation.
Fig. 20. English Sparrow, 13 days—age of hatching.
Fig. 21. English Sparrow, 2 days after hatching.
Fig. 22. English Sparrow, 4 days after hatching.
Fig. 23. English Sparrow (older age unknown).
Fig. 24. English Sparrow, just flying (probably about 2 or 3 weeks).
Fig. 25. English Sparrow, adult.

noticeable. At this stage the optic vesicle is reduced to a shallow cavity and a marked difference is seen in the thickness of the two walls.

The edges of the epiblastic pit approach each other and finally unite to form the lens capsule. Later this is completely separated from the epiblast, which forms a continuous layer over it. The optic cup becomes deeper and deeper until the two walls unite, thus wholly



Enlarged View of the Right Eye of the English Sparrow, Showing the Distribution of the Nerves over the Front of the Eye, the Skin having been Removed with the Exception of the Margin of the Lids. (Wood and Slonaker.)

g, Lachrymal gland; *im*, inferior maxillary nerve; *io*, inferior orbital nerve; *l*, lachrymal nerve; *sm*, superior maxillary nerve; *so*, superior orbital nerve.

obliterating the primary optic vesicle. The inner layer soon becomes much thicker than the outer and finally develops into all the layers of the retina except the pigment layer which is formed by the outer wall.

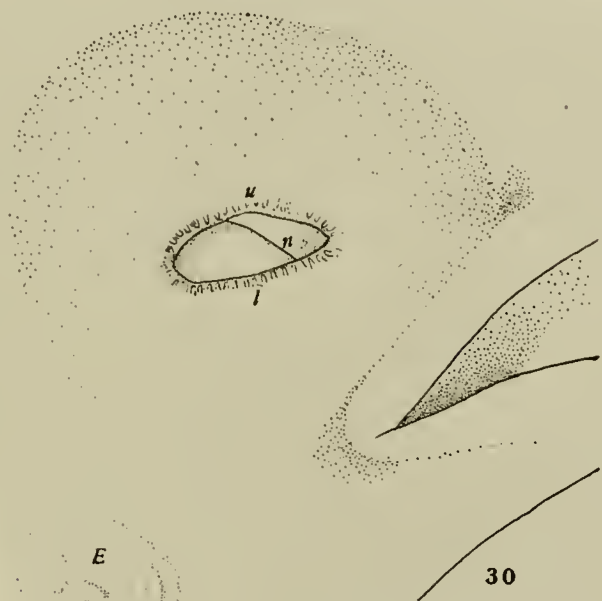
All portions of the wall of the optic vesicle do not grow at the same rate. The cells on the dorsal side multiply more rapidly than the others and thus produce an unsymmetrical outgrowth.

The retardation of growth of the ventral cells prevents the complete closing over or uniting of the ventral border of the optic cup at this stage. This space or groove, which is left, is known as the choroid fissure. It is more clearly understood by examining Fig. B, which represents the view of a section made at right angles to the paper and along the line s-s of Fig. 3, A.

This stage is reached in the chick at the age of about 44 hours' incubation (Fig. 4). The epiblast is very thin and enables one to

easily perceive the lens, the horseshoe-shaped rim of the optic cup (op v) and the wide choroid fissure below.

As development advances this fissure is gradually narrowed by the proliferation of the cells of the walls in this region, so that by the time



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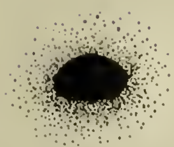

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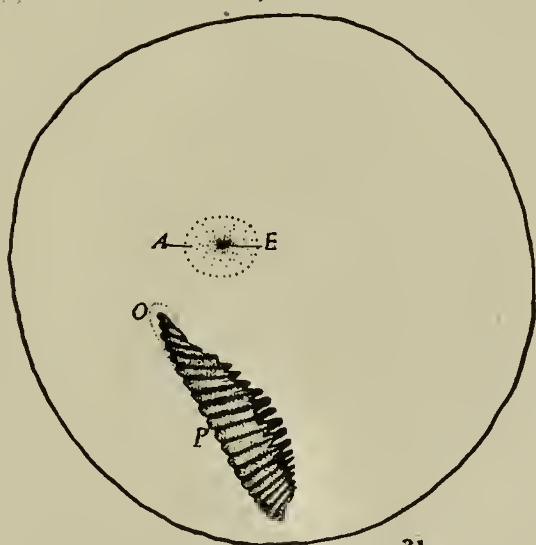

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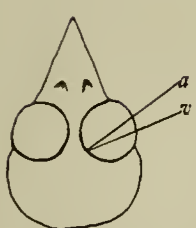

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Fig. 30. Embryo at the age of 13 days, at the time of hatching. For the sake of clearness the feathers have been omitted. *E*, ear; *l*, lower lid; *n*, nictitating membrane; *u*, upper lid. The margins of the lids begin to show the thickened convoluted appearance. x 15.

Fig. 31. View of the fundus of the adult right eye after the removal of the anterior part by sectioning through the equatorial region to show the area centralis *(A)*, the fovea *(F)*, optic nerve entrance *(O)*, and pecten *(P)*. The pecten stands almost vertical in this view. x 18.

Fig. 32. Diagram of a horizontal section through both eyes showing the optical axis *(a)* and the angle *(v)* at which Fig. 31 was made.

Fig. 33. Fovea and area centralis of Fig. 31 much enlarged. The horizontal diameter is seen to be decidedly greater than the vertical. x 100. (Wood and Slonaker.)

the chick has reached the age of 96 hours it is seen as a mere cleft (Fig. 5, Ch s). The edges of the walls of the fissure have not only grown closer together but the lower rim of the optic cup, which was retarded, has grown forward until the whole front is symmetrical. The walls of the choroid fissure unite first at the rim of the optic cup. This gradually works backward until no trace of the fissure is left in the chick by the ninth day of incubation.

Judging from external appearances and development of different structures, the earliest stage secured of the English sparrow (about two days) corresponds very closely to that of the four and a half day chick. This represents a stage further advanced than that which has just been described.

MAMMALIA.

This is the highest class of vertebrates and includes all those viviparous, warm-blooded animals which are provided with superficial dermal glands for the purpose of secreting a fluid called milk for the nutrition of the young. Man, all quadrupeds, seals, whales, and bats are examples of this class.

There are seventeen orders of mammals at present living.

Order 1, Monotremata.—This order includes two remarkable Australian forms, the Platypus and the Spiny Anteater.

Order 2, Marsupialia.—This order includes Kangaroos and Opossums.

Order 3, Edentata.—This order includes the Anteaters and Armadillos.

Order 4, Bradypoda, or Sloths.—These are tailless, arboreal animals inhabitating South America.

Order 5, Sirenia or Manatees.—This small group of sea-weed-eating marine animals, of a somewhat fish-like habit and form, includes the Dugong of the Indian Ocean and the South American Manatee, Mermaid or Sea Cow.

Order 6, Ungulata, includes all those herbivorous, hoofed mammals whose extremities are used solely as organs of progression. The ungulates include the Horse, Tapir, Rhinoceros, and Pig. A division of them is sometimes made of those that chew the cud—Ruminants—such as the Cow, Camel, Llama, Deer, Giraffe, Antelope, Goat and Sheep.

Order 7, Cetacea (Whales), includes Porpoises and Dolphins.

Order 8, Pinnipedia.—This small order consists of the Seals and Walruses.

Order 9, Carnivora.—The flesh-eating mammals are Hyenas, Cats, Dogs, Bears, Lions, Tigers, Wolves, Panthers, Leopards; the Skunk,

Weasel, Marten, etc. It also includes the Rodents, some of which are Mice, Guinea-pigs, Hares, Rabbits, Squirrels, Beavers.

Order 12, Proboscidea (Elephants).

Order 13, Prosimii.—These are the Lemurs, monkey-like animals, chiefly confined to the Island of Madagascar.

Order 14, Insectivora.—This order consists of the Shrews, Moles, Flying Lemurs and Hedgehogs, which, as their name implies, feed on insects and worms, and other small animals.

Order 15, Chiroptera (Bats).

Order 16, Primates.—This, the last order of mammals, includes the most highly organized members of the entire animal kingdom—the Monkeys, Apes, and Man.

EYEBALL, GLOBE OR BULB OF VERTEBRATES.

Shape of the eyeball. Although we are accustomed to think of animal eyes as uniformly spherical, or nearly so, that is far from the case in many vertebrates. The round shape is, it is true, seen in Man, Monkeys, the smaller Mammals, and in Amphibia, but in most animals the three principal ocular diameters—antero-posterior, vertical, and transverse—differ greatly, the antero-posterior axis being generally the shortest.

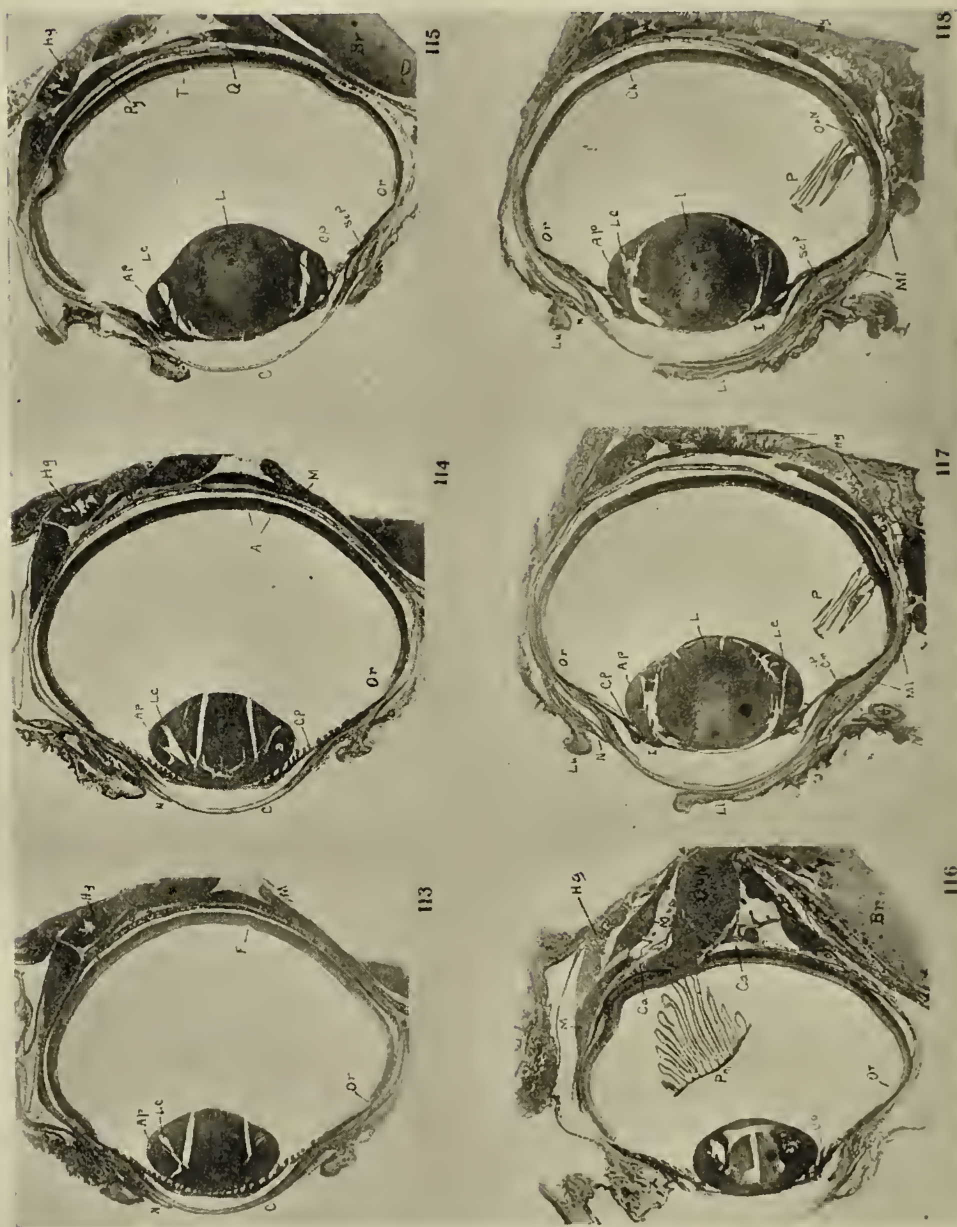
These three diameters are about the same in the Beaver, the Rat, the Lynx, and the Raccoon. The antero-posterior is shorter than the transverse by 1 mm. in the Wolf, by 2.5 mm. in the Rabbit, by 5 mm. in the Deer, and by 7 mm. in the Ox.

In nocturnal Birds of Prey the transverse and antero-posterior diameters are about equal. In the diurnal Raptores (the Eagles and Buzzards, for example) the antero-posterior diameter is shorter—an important matter in aquatic Birds. The eye of the Duck measures 12 mm. from before backward, 15 mm. vertically and 16 mm. in the transverse diameter.

Similar conditions prevail in marine Turtles, while the eyes of the Chameleon, Frog, and Garter Snake are nearly spherical.

Eyeball. The globe of the adult Sparrow approaches in shape that of an irregular spheroid, or of an acorn, the length of the antero-posterior axis being to the horizontal equatorial diameter as 1:1.20. The spheroid shape of the eyeball is preserved by the cornea, whose radial measurements are less than those of the larger globular body upon which it is superimposed. The ovoid outline of the eyeball behind the iris plane may easily be seen in the Sparrow as in most birds.

The bulbar diameters vary with the age of the bird; in recently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Microphotographs of Sections Through the Eye of a Young Sparrow Just After it Had Made Its First Trial Flight, about 12 or 14 Days After Hatching. (Wood and Slonaker.)

A, Area centralis; *Ap*, annular pad of the lens; *Br*, brain; *C*, cornea; *Ca*, thickened portion of the scleral cartilage surrounding the optic nerve entrance; *Ch*, choroid; *Cm*, ciliary muscles; *Cp*, ciliary processes; *F*, fovea; *Hg*, Harder's gland; *I*, iris, *L*, lenticular portion of the lens; *Lc*, lenticular chamber; *Ll*, lids; *Lu*, upper lids; *M*, eye muscles; *Ml*, muscle of the lower lid; *N*, nictitating membrane; *Op N*, optic nerve; *Or*, ora serrata; *P*, pecten; *Pm*, free margin of the pecten showing how the folds are united into a median ridge; *Py*, pyramidalis; *Q*, quadratus muscle; *Sc P*, scleral plates; *T*, tendon from the pyramidalis muscle.

Fig. 113.—Horizontal section of the left eye of a young sparrow about 14 days after hatching. Section passes through the center of the fovea but to one side of the center of the lens. The fovea shows a marked depression. x 10.

Fig. 114.—Same series as Fig. 113, passing through the area centralis at the edge of the fovea. x 10.

Fig. 115.—Same series as Fig. 113, passing through the center of the lens. The lens appears as the typical adult lens. The breaks and spaces are due to hardening and are not normal. The pyramidalis *(Py)* with its tendon *(T)* passing through the loop of the quadratus muscle *(Q)* is seen. x 10.

Fig. 116.—Same series as Fig. 113 at a lower level some distance below the proximal portion of the nerve entrance. The free margin of the pecten *(Pm)* shows how the folds merge into a single median densely pigmented mass. x 10.

Fig. 117.—Vertical section of the right eye of the same bird as Fig. 113. Section passes through the center of the lens and the distal end of the pecten .030 mm. beyond the last trace of the optic nerve. The anterior part of the lens from which the annular pad is derived appears as a mere line. The ciliary processes are closely attached to the lens. The ciliary muscles appear as a dark area lying just inside the scleral plates. The muscle of the lower lid can be traced back to the posterior part of the eye-socket where it is closely attached to the orbital side of the inferior rectus muscle. x 10.

Fig. 118.—Same series as Fig. 117, showing the place where the most distal part of the optic nerve penetrates the retina. x 10.


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133
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Microphotographs of Horizontal Sections Through the Head of the Adult Sparrow, Showing the Relation of the Eye to the Socket, the Nerve Entrance and the Optic Chiasma, Pecten, Fovea and the Different Parts of the Eye. (Wood and Slonaker.)

AF, axis of vision; *Ap*, annular pad of the lens; *Art*, artifact, space due to hardening; *Bv*, blood-vessels of the socket; *Ch*, choroid; *Chs*, Chiasma; *Cm*, ciliary muscles; *F*, fovea; *Hg*, Harder's gland; *Lc*, lenticular chamber; *Lg*, lachrymal gland; *M*, eye muscles; *Mp*, median plane of the head; *Op N*, optic nerve; *Or*, ora serrata; *P*, pecten.

Fig. 132.—Section through the center of the fovea of the right eye. The section passes a little to one side of the center of the lens.

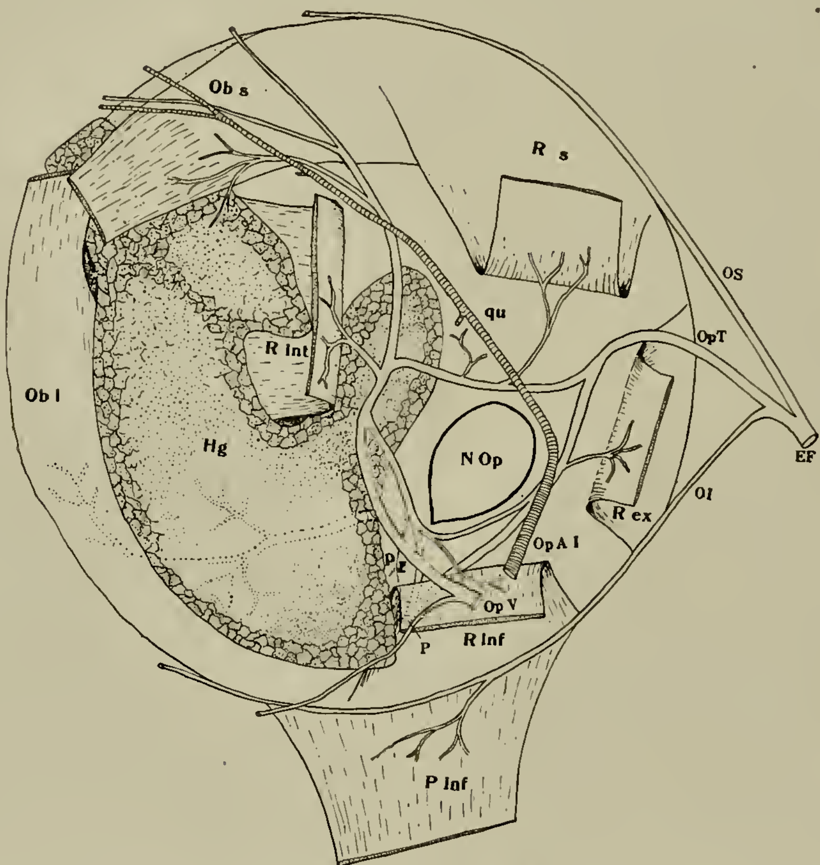
Fig. 133.—Section through the center of the fovea and lens of the left eye.

Fig. 134.—Section at a lower level, passing through the nerve entrance, pecten and chiasma.

Fig. 135.—Section at a still lower level, showing the proximal insertion of the internal and external rectus muscles.

hatched specimens they are, following the usual rule in vertebrates, shorter than in developed adults. For example, in a Sparrow 4 days old both the axial and horizontal diameters were 6 mm.; two to three weeks old the axial diameter was 6.20 mm., and the vertical diameter 7.0 mm. In the adult birds an average of five individuals showed the axial diameter 6.30 mm., and the horizontal-equatorial diameter 7.4 mm.

So far as we have observed, sex exerts no influence upon the size of the eyeball.



Posterior View of the Right Eye of the Sparrow, Showing the Venous Supply to the Eyeball and Accessory Structures. x 20. (Wood and Slonaker.)

EF, External facial; *Hg*, Harderian gland; *N Op*, optic nerve; *Ob i*, inferior oblique; *Ob s*, superior oblique; *OI*, infra-orbital; *Op A I*, internal ophthalmic artery; *OpT*, ophthalmo-temporal vein; *OpV*, ophthalmic vein; *P*, point where vein from the pecten pierces the sclerotic; *P inf*, inferior palpebral muscle; *Py*, pyramidalis muscle; *qu*, quadratus; *R ex*, external rectus; *R inf*, inferior rectus; *R int*, internal rectus; *R s*, superior rectus.

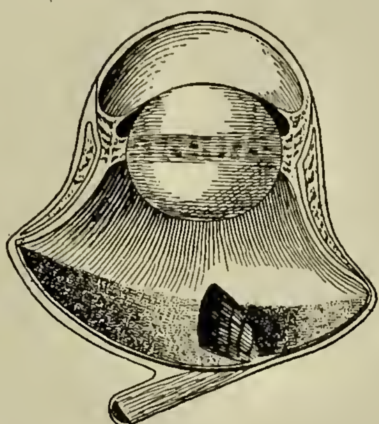
The eyeball posterior of most birds as stripped of the adherent muscles, glands, etc., has a dark, almost black, appearance, due to the abundant deposits of pigment in the ocular coats.

As a rule, the ocular bulb in Birds is spherical or almost spherical in form, although, as will hereafter be noticed, in many birds this shape is much modified. In front its curvature is considerably modi-

fied by the cornea, which in all birds of prey is more convex than in other vertebrates. In most birds the eyeballs are placed and directed laterally, so that they have monocular or incomplete binocular vision. In Birds of Prey they are situated anteriorly and directed straight forwards.

It is however, in Fishes that relatively small antero-posterior axes are most marked; their eyes ordinarily take the shape of an ellipsoid with three quite unequal axes. The measurements of the Pike's eyeball are respectively 10, 14 and 12 mm.; the Cod's, 26, 44 and 40 mm.; the Shark's 40, 66 and 58 mm.

In studying *variations in shape of the globe,* there are three parts that especially present these changes in form—the cornea, the fundus oculi, and that part of the ocular wall bordering on the cornea, which Leuckart has called the *intercalary zone.* Internally this region is



Eye of the Eagle Owl, showing the Peculiar form of the Globe.

bounded by the termination of the retina posteriorly; anteriorly by the angle of the anterior chamber.

The intercalary area is of great importance in Birds. In the eye of the Eagle-Owl (Bubo) the cornea is connected with the deeper parts of the eye by a kind of funnel whose external surface is concave. To the internal surface of this infundibulum the ciliary body is attached while the background of the eye, shaped like a capsule, shallow but relatively wide and of large curvature, is covered by the choroid and retina.

The eye of this Great Owl has a depth of 39 mm., of which the cornea occupies 10.5 mm., and the intercalary zone 17.5 mm., leaving only 11 mm. for the remaining (fundal) third. The diameter of the posterior orifice of the *bulbar funnel,* just referred to, is 41 mm., while that of the anterior opening is only 25, thus assuring the bird a maximum retinal image with a minimum of bulbar volume.

However, the intercalary area is far from being of equal importance

in all avian eyes, being very small in the Ostrich and the aquatic Birds. In every instance, however, it joins the fundal third at an acute angle directed forwards.

In Fishes the intercalary zone is much reduced in size, so that the ocular capsule looks as if it were closed by a nearly flat cornea.

Some Deep Sea Fishes have a peculiarly shaped eyeball in which the intercalary zone is much extended from before backwards, and the whole organ takes the form of a telescope. Moreover, the eyes are close together, with their axes nearly parallel. *This arrangement allows of binocular vision* and is quite exceptional in Fishes, being found in different species of Argyropelecus among the *Gigantura.* These eyes have other peculiarities; the globes are nearly immobile in their orbits; the iris takes little or no part in accommodation; and

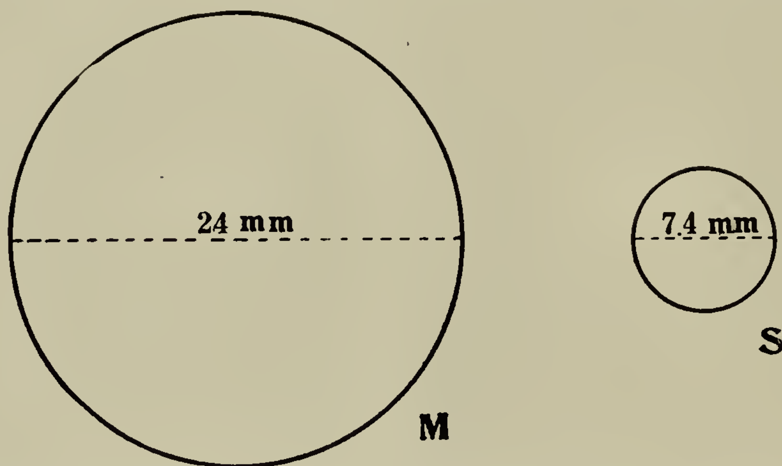


Diagram Showing the Relative Size of the English Sparrow's Eye as Compared with that of Man. The circles are drawn with the equatorial diameter in each instance. x 2. (Wood and Slonaker.)
M, man; S, sparrow.

there is a sort of *accessory retina* intended to collect the images reaching the interior of the eye from the lateral areas of the field of vision.

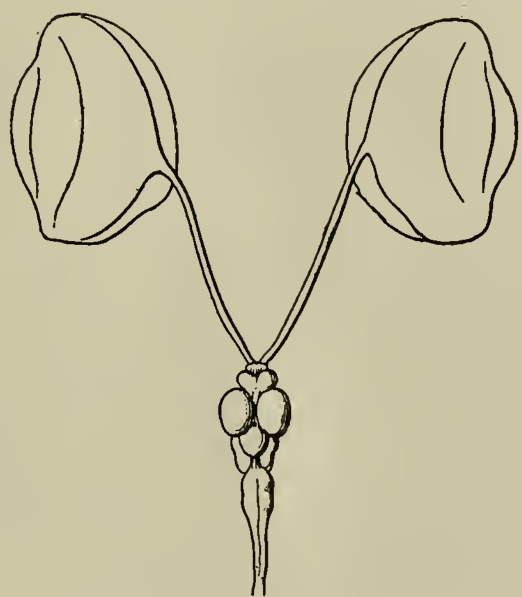
Size of the eyeball as compared with the rest of the body. Haller, long ago, noticed that there is no necessary relation between the volume of the eyeball and the size of the animal. Among the Felines, for example, the Wild Cat has larger eyes than the Lion. The eyes of the Whale are very small as compared with its huge bulk. The Elephant and the Rhinoceros have smaller eyes than the Horse, whose eyes (antero-posterior diameter 41 mm.) are, with those of the Ostrich, the largest of terrestrial animals.

Among domestic animals, according to Emmert (*Zeitschr. f. vergl. Augenheilk.,* 1886), the ocular volume to body weight decreases in the following order: Cat, Rabbit, Dog, Sheep, Calf, Horse, Man, Cow, Pig, Ox.

Some animals have very large eyes, considering their bodily size; Birds, for instance. The eyes of the Owl and the Swift occupy one-third of the whole head; the Swallow's eyes weigh one-twentieth of its body.

Serpents and Amphibians have relatively small eyes. For example, the eye of the Garter Snake (weighing 2 ctgm.) represents the one-thousandth part of its body weight.

The eyes of Fishes are, as a rule, relatively and actually quite large, especially those of some Deep Sea Fishes. The eye of the Cod is about the size of a Horse's eye, while the Shark has a still larger organ. The eye of *Orthagoriscus* sometimes reaches the volume of an orange,



Eyes and Brain of (the Fish) *Lophius piscatorius.* (Beer.)

while the lens of such an eye is as large as the human crystalline. It is much the same with Fresh Water Fishes. On the other hand, Silurians and Eels, that prefer a muddy habitat, have relatively small eyes. As we know, blind Fishes and other blind animals (see Vol. II of this *Encyclopedia*) have small and defective eyes.

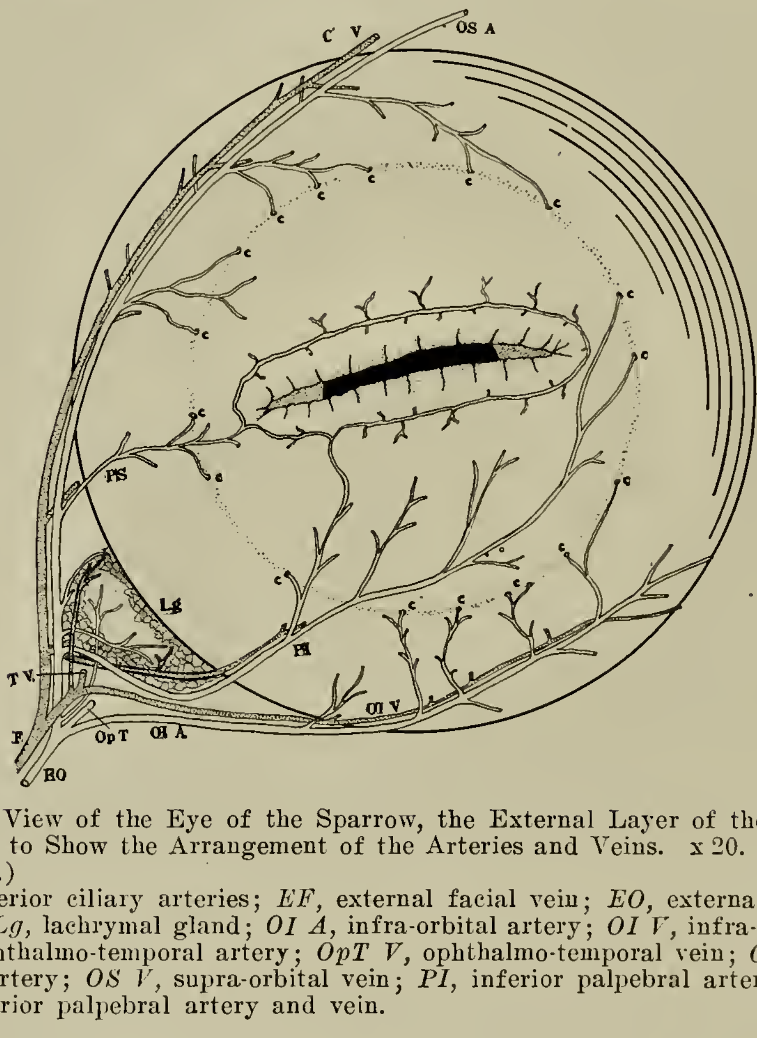
It is interesting to note the *relation in size between the brain and eye of Fishes.* The illustration shows the marked disparity between the two in *Lophius piscatorius.*

One may conclude from a study of the subject that large eyes, furnishing a correspondingly large and well-defined image, are found in animals that rapidly move the eyes, head, or whole body (or all together) in such a manner as to require distinct and instantaneous vision. We find these requirements (and large eyes) in Birds—night birds especially—and in the mammalian Carnivora.

ORBITS OF VERTEBRATES.

Much of the material for this subject has been abstracted from Kalt's admirable contribution to Vol. III of the *Encyclopédie française d'Ophtalmologie.*

Orbital cavity. These spaces generally take the shape of a cone or pyramid whose apex, corresponding to the optic canal, is crossed by the lesser wing of the sphenoid bone. In Man and the higher Monkeys the orbital walls are formed above by the frontal bone, externally by

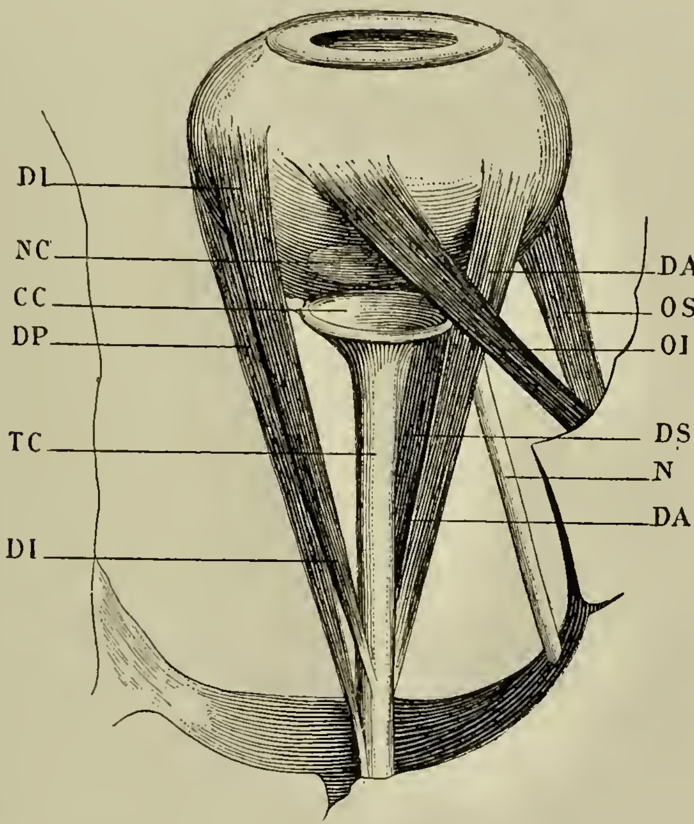


Front View of the Eye of the Sparrow, the External Layer of the Lids being Removed to Show the Arrangement of the Arteries and Veins. x 20. (Wood and Slonaker.)

c, Anterior ciliary arteries; *EF*, external facial vein; *EO*, external ophthalmic artery; *Lg*, lachrymal gland; *OI A*, infra-orbital artery; *OI V*, infra-orbital vein; *OpT*, ophthalmo-temporal artery; *OpT V*, ophthalmo-temporal vein; *OS A*, supra-orbital artery; *OS V*, supra-orbital vein; *PI*, inferior palpebral artery and vein; PS, superior palpebral artery and vein.

the orbital process of the malar bone and the larger wing of the sphenoid, and internally by the lachrymal and the *os planum* of the ethmoid. The floor of the cavity is mainly formed by the superior maxilla. These four walls enclose the cavity in a bony cup broken only by the inferior orbital fissure which communicates with the pterygo-maxillary fossa. It is noticeable that this fissure is narrower in Monkeys than in Man. On the other hand, it becomes considerably

larger in other vertebrates, there being an ample communication with the temporal fossa. At the same time the floor of the orbit diminishes in area and in some instances is entirely wanting. In a number of these latter instances, e. g., the frog and many fishes, the orbit is a mere diverticulum of the temporal fossa and is separated below from the pharyngeal cavity only by the pterygoid muscles, and of the osseous structures there remain only the frontal bone and the lesser wing of the sphenoid.



Orbital Contents, Showing Especially the Muscles and Cartilaginous Support, of a Shark's Eye. (Motais.)

The cup, CC, of the cartilaginous column TC, articulates with a tubercle, NC, of the thickened sclera. N, the optic nerve; OI, inferior oblique muscle; OS, superior oblique muscle; DI, inferior rectus; DA, anterior rectus; DP, posterior rectus; DS, superior rectus.

Unlike Man and Monkeys, whose orbital margins are well developed and whose orbital axes approach the median line, those animals (Rodents, Insectivora) in which the interorbital bones are strongly developed so as to furnish a solid support for powerful maxillæ, the orbital ring is incomplete—especially externally. Between these are the Carnivores, in which the malar and frontal apophyses are united by a fibrous band.

In those animals whose superior maxilla is movable the eye must

be defended by accessory bony structures. Thus, one sees in the eyes of the osseous fishes complete bony circles; also an arrangement of the same character, though not so complete, in certain birds, notably the Woodcock and the Parrot.

Lower in the vertebral scale than man the orbits tend to join one another posteriorly; they are fused in such animals as the Hare and the Antelope. In Birds, Lizards, Crocodiles, Turtles, and the bony Fishes the nasal cavities are but slightly developed, so that each orbit approaches the median line and is separated from its fellow only by a thin bony or cartilaginous partition. In these animals, also, the optic foramen of the two orbits is a single, common opening, found just where the interorbital wall joins the cranium.

The orbital axes. In Man, Monkeys and the Owl the orbits have marked antero-posterior axes. The intersection of the planes formed by the base of each orbit forms an angle which varies greatly in the animal series. Leuckart found this biorbital axial angle to be 168° in the Orang. In Man and the higher Monkeys there is also an extensive binocular field of vision. The biorbital angle increases anteriorly as the axes diverge, while the superimposed area of the fields correspondingly decrease. In the Carnivora it ranges from 80° to 100°, in Ruminants 40° to 50°, Birds about 30°, and in Fishes 20° to 30°.

With this lateral deviation of the orbital axes is associated an orientation upwards. This is particularly the case in animals of small size—Amphibia, Fishes and Rodents. In these instances there is probably a binocular field above the horizon which is lacking when the animal looks straight ahead.

In the Fish *Uranoscopus* the plane of each orbital base is practically that of the neighboring dermal covering.

Periorbital membrane. In all Vertebrates the ocular apparatus is enveloped in a funnel-shaped, fibrous covering, whose apex is attached about the entrance of the optic nerve. The base of this capsule is attached to the lids or, as in Mammalia, is lost in the tissues at the margin of the orbit.

In Fishes this funicular membrane is surrounded on all sides by the muscles of mastication. The infolding membrane is much less developed in Reptiles, Birds, and some Mammalia, while in Man and Monkeys, where the bony septum separates the eye from the neighboring organs, the periosteum and periorbital membrane are indivisible.

In Amphibians, Lizards, and Birds the periorbital membrane is supplied with striped fibres derived from the masticatory muscles. In the Frog (as well as in Birds and Lizards) these fascicles, attached

behind to the pterygoid bone, perform the function of oculo-motor muscles, and act as depressors of the lower lid. Analogous muscular bundles, arising from the pterygoid bone and attached to the orbital membrane are found in Batrachians, Reptiles, Fishes, and, perhaps, in Birds. We may, in consequence of these facts conclude that this striated muscular apparatus originates in the muscles of mastication.

In the membranous wall of the orbit of certain Flat Fishes (Pleuronectes), and near the wall dividing them, is placed a conical sac filled with liquid and directed backwards. This sac, the *recessus orbitalis,* is provided with muscular walls and communicates with the orbital cavity by one or more orifices. When the sac contracts it discharges its contents into the orbit and causes a momentary protrusion of the whole globe.

The orbital contents. In addition to the eyeball, the ocular muscles, blood-vessels and nerves the vertebrate orbit nearly always contains an abundance of fat that acts as a sort of padding or support to the globe. In Fishes this adipose tissue is replaced by gelatinous tissue. In the Shark the mobile orbital tissues do not afford the eyeball sufficient support, so that a column of cartilage, attached to the apex of the orbit, projects forward to the posterior surface of the globe, bearing a saucer-like expansion in which the eyeball is held.

The orbital cavity of Birds is almost spherical. Its development is most marked in the diurnal and nocturnal birds of prey, where it occupies a third or even half of the entire head. Although the bones of the skull are united at a very early period, the walls of the orbit are formed above by the frontal bone (which protect the greater part of the eyeball) and make a prominence in front. They also bound the cavity at the back. In the Owl the concavity is interrupted posteriorly by the auditory foramen, that opens into the orbit.

In front the floor of the orbit is partly formed by the lachrymal. The two orbits are separated by a thin partition which occasionally remains cartilaginous at its center. According to Milne-Edwards this partition is largely formed by the ethmoid in front, and behind by a prolongation of the presphenoid.

The posterior segment of the orbital cavity is open and communicates with the temple; below, the osseous floor is missing almost entirely.

The *periosteum* is spread over the floor of the orbit and behind it, completing at these points the walls of the cavity. It is lined externally by the temporal muscle. The depressor muscle of the lower lid seems to be developed from the thickest part of the periosteum in its infero-posterior part.

The capsule of Tenon. In most vertebrates, as in man, the fibrous

capsule of the eyeball *is attached to the globe, in front, around the cornea and behind, about the optic nerve.* How can a sphere rotate in a covering which is attached to it at its two poles? It is only necessary to put such a question in order to settle it. Without returning to the above mentioned study to which we refer, we recall that in reality the eyeball in its rotation drags (with it) all its cellular—fatty or gelatinous—surroundings, the optic nerve and the capsule itself, all of which are carried along in the direction of the rotation. This is the principal phenomenon. In addition, due to the elasticity of the capsule and its external attachments, the proper movement of the eyeball is a little more extensive than that of the capsule; whence a certain amount of slipping of the eyeball upon the capsule, very small, it is true, but sufficient to produce a rudimentary sereuse. This is the true mechanism of the eyeball. We do not doubt that this simple explanation will put an end to an error which is surprising as much for its obviousness as for its persistence.

It may in a general way be stated that the deeper surface of the fibrous capsule of the globe of Vertebrates is lined with a very thin membrane which can be separated by the scalpel, and which is covered over by pavement endothelium. In a certain number of Teleosteans this membrane reaches to the cornea; in most Vertebrates it terminates at the line of adherence of the anterior capsule to the globe, that is to say, at the level of the tendinous insertions of the recti and oblique muscles. At this point, reduced to its epithelial lamella, it folds over the sclerotic. The two walls are united by more or less thick and numerous cellular trabeculæ; the partitioned space which they circumscribe forms the cavity, or rather the slit of Ténon, this cavity being merely potential in the normal state.

The capsule of Ténon in mammals presents the following particular characteristics: its thickness which is generally great, sometimes remarkable; in some species the existence of ligamentous wings or accessory tendons; its relations with the choanoide muscle except in pinnates, where this muscle does not exist.

It appears from this explanation that the aponeurosis of the orbit or the capsule of Ténon as a whole is constructed uniformly in the entire series of vertebrates; that the variations in detail, which occur, are always due to variations in the muscular apparatus.

Check ligaments or accessory tendons. Up to this point we have considered the aponeurosis only as an enclosing apparatus (appareil de contention) of the muscles and the eyeball. This is, in fact, its chief rôle, but this is not all, at least in a large number of vertebrates.

It must also be considered as an aponeurosis of insertion of the ocular muscles.

The muscles of the eye are inserted in the depth of the orbit and in the ball. At the level of the equator of the eyeball, at the point where the muscle encircles the ball to reach the sclerotical insertion, its sheath is firmly fastened upon it and divides into two layers, of which the superficial one (membranous entonnoir) leaves it and proceeds to attach itself directly, without following in the curve of the muscle, to the orbital rim. One can prove, in all vertebrates, either by a traction on the body of the muscle or by electrification, that during the contraction of the muscle, this part of the aponeurosis contracts (se tend), that it draws the muscle outside to its own insertion so that the direction which the whole anterior part of this (muscle) takes is only the result of two forces which draw it, one toward the tendonous insertion of the sclerotic, the other toward the aponeurotic insertion at the orbital rim.

Ténon had perfectly explained the physiological purpose of this double insertion in man. "We ourselves have studied for a long time the action of the wings on the muscles of man (*Anatomie et physiologie de l'appareil motum oculaire de l'homme,* +1). Now we can extend to vertebrates the conclusions at which we arrived. In a state of repose the muscles encircle the globe. During contraction they tend to straighten their curve and compress the ocular organ at the equator. The eccentric contraction of the aponeurosis prevents this compression. The more energetic the contraction is the more the aponeurosis 'se tend' and the less compression of the ball becomes possible. This shows us why, in certain species, that part of the aponeurosis situated in front of the muscle becomes more or less thick and sometimes forms a protuberance so pronounced above the 'entonnoir,' that it seems distinct from it (ligamentous wings, man). Sappey has demonstrated that smooth muscular fibres develop in these wings. In many vertebrates one or more muscular bundles (faisceaux) often considerable, separate from the recti and oblique muscles and reinforce the aponeurotic band which they thus transform into a true accessory tendon.

"Why do these wings only develop in certain species?

"It would be difficult for us to answer this question now. It does not seem that these wings can be attributed entirely to the power of the muscles. For example, next to the carnivores, which have wings, we find ruminants which have large muscles and no wings. Among fishes the tunny, the orgathoriscus mola, the sturgeon have not only wings but remarkable orbital tendons and many neighboring species

in which the ocular muscles are also developed have neither wings nor accessory tendons.

"In this connection we can only repeat an observation which we have already made; in general, when the wings exist, the membranous 'entonnoir' is less thick in their intervals; when the wings do not exist, the entire membranous 'entonnoir' becomes more solid.

"In the first case, the muscular effort is concentrated in large part on the aponeurotic band situated in front of the muscle; in the second case, it is distributed almost equally on the entire fibrous cone."

Nevertheless let us note that we have found wings and accessory tendons only in Fishes and Mammals; that is to say, in the two classes of vertebrates where ocular muscles are the most developed.

EXTRAOCULAR MUSCLES OF VERTEBRATES.

These are uniformly six in number, four *recti* muscles and two *obliques.* In most vertebrates the *recti muscles* are arranged in the form of a funnel in the rear of the eyeball. Their posterior insertion is made, in general, on the circumference of orbital foramen, which furnishes a passage for the optic nerve. In Fishes, however, this foramen being often carried far forward into the orbital cavity, the muscles are inserted in the rear and outside, often at the bottom of a canal called the sphenoidal canal, which extends underneath the base of the skull. The axis of the muscular funnel then makes a large angle with the anterior-posterior axis of the eyeball.

The motor muscles of the eye are generally better developed in the fish, whose head is almost immobile, than in the birds. In the pike, the scomber, and the cyprinæ, the sphenoidal canal, which receives the muscles, extends sometimes to the occipital. On the other hand, the canal is hardly shown in the codfish and the silurus.

The sphenoidal canal is not confined to the fish. It exists also in the Saurians and Crocodiles.

The Rays and the Sharks have a large, deep orbital cavity. The eyeball is carried by a cartilaginous trunk, bell-shaped in front, and the muscles are inserted by their posterior end at the foot of the trunk.

Except in cartilaginous fish, whose muscles can have a length equal to three times the length of the eyeball, the length of the recti muscles scarcely exceeds twice the depth of the globe and it does not reach this figure in the birds, whose muscles are particularly short and slender. We will say more concerning the Reptiles and Batrachians. In all these animals the movements of the eyeball are very limited, often almost nil.

In laterally placed eyes the term *anterior rectus* is used, instead of the *internal rectus,* and *posterior rectus* instead of *external rectus.*

The *oblique muscles* are also found in all vertebrates. In the Mammifera, with the exception of the Cetacea, their posterior insertion is different for the *superior oblique* and for the *inferior oblique.* The superior oblique takes its insertion in back in the neighborhood of the recti muscles, and its tendon is fixed upon a pulley attached to the supero-internal rim of the orbit, before it reaches the eyeball. The inferior oblique is attached, on the contrary, by its fixed insertion, in back of the infero-internal portion of the orbital periphery. But in most vertebrates the two muscles possess an insertion very near the internal side of the orbit and enclose symmetrically the equator of the eyeball.

The mobile insertion of these muscles is made habitually at the side and little in rear of that of the superior and external recti muscles. In Fishes, however, the oblique muscles are inserted in front of these last muscles. In Birds the oblique inferior passes outside of the external recti.

It is the same in the Elephant and the Chimpanzee. In the Tiger, the tendon of the two oblique muscles divides in two; one of the portions passes inside, and the other outside of the two recti muscles. In the Lion, the bifurcation takes place only in the tendon of the large grand oblique muscle. In the Tortoise, it is this muscle which is divided while the inferior oblique passes through a cut (gash) which is offered it by the inferior recti (Leuckart).

In the Carnivora, such as the Dog, the oblique muscles play the rôle of rotators. It seems also that their simultaneous contraction has the effect of carrying the eyeball forward and to make the cornea come out between the eyelids.

In the orbits of Birds we find the aforementioned six muscles designed to rotate the eyeball, and two others that control the movements of the third eyelid. The straight muscles or *recti* muscles rise from the part of the optic foramen and come forward to be attached to the eyeball. These muscles are the *superior, inferior, external* and *internal recti* muscles, and are attached, as in other vertebrates, near the equator of the globe.

The two *oblique* muscles rise from bony origins in the anterior segment of the orbit and are inserted in the sclerotic, the superior oblique on a large surface which is frequently curvilinear, slanting obliquely from back to front and from outside to inside, sometimes on a level with the superior rectus muscle and sometimes behind this muscle, which covers it. The relations between the superior rectus muscle and

the superior oblique, observed also in Reptiles (Saurians, Chelonians), are constant in birds. In the Strigidæ (Owls) the two oblique muscles are rudimentary.

Muscles of the third eyelid. The motor apparatus of the winking lid is even more remarkable in Birds than the same organ in Batrachia and Reptiles, and has attracted the attention of anatomists since the earliest times. It was described by Perraut in 1722, afterwards by Petit, Hunter, Cuvier and others.

This special winking apparatus is made up of two muscles: the *quadratus* muscle and the *pyramidalis,* inserted into the posterior hemisphere of the ball, behind the scleral insertions of the recti muscles.

The *quadrate muscle,* which is the larger and more developed, is inserted in the sclerotic just behind the insertion of the rectus superior muscle. Its attachment fills in the space between the superior and internal recti muscles on the superior edge of the latter. From this insertion all its fibres are directed toward the optic nerve. The free extremity of the quadrate muscle is about one-third as large as its size at insertion. Thus it presents a triangle with truncated apex rather than a *square,* as its name indicates. At this point, instead of having another insertion, fixed or mobile, the muscle abruptly ends in a tendon which folds on itself to form a fibrous loop.

The *pyramidal muscle,* which is much smaller, is inserted under the anterior half of the inferior rectus muscle and on a line 3 or 4 mm. in front of the edge of the muscle. It then reaches the anterior surface of the optic nerve and ends in a tendon which passes through the loop of the quadrate muscle. The tendon passes through the loop encircling the superior surface of the optic nerve, then enters a groove in the sclerotic, where it is held by a contraction of the capsule of Ténon. It then passes from within out, between the inferior and posterior recti muscles—nearer to the last—interrupts the bony circle about the nerve (in the owl it is attached to an apophysis of the bony circle) and reaches the posterior-inferior angle of the third eyelid.

In Birds, Saurians, Crocodiles and the Tortoise are found two muscles whose contraction has the effect of drawing the nictitant membrane towards the cornea. In the birds of prey, this muscular apparatus attains its highest degree of perfection.

In the Buzzard, the quadrate has the form of a flat muscle, applied to the upper half of the base of the eye. At its anterior edge the muscle is inserted in the upper margin of the base (fond), beneath the superior recti and the large oblique muscles. From there the fibres are directed from front to rear to terminate upon a curved fibrous strip with an inferior concavity and turned towards the optic nerve.

The fibrous strip is not solid, in its thickness is hollowed out a canal destined to permit the passing of the filiform tendon of the pyramidal muscle of which it remains for us to speak. The surface of the pyramidal muscle has the form of a triangle whose base is inserted by its fixed end on the sclerotic, near the internal margin of the inferior recti muscle.

The body of the muscle, directed upwards, thins out rapidly to the point where it is continued with a very long filiform tendon. This tendon engages in the manner of a curved curtain-rod in the groove which the fibrous strip of the quadrate muscle offers it. After winding round the optic nerve for some distance, the tendon leaves the canal and is directed downward to reach the lower margin of the base (fond) of the eye (the eye of birds of prey possesses a slightly curved base united with a sort of funnel which carries forward the cornea). Arrived at this point the slender tendon is directed forward, going along the inferior external part of the eyeball, between the inferior recti and external recti muscles. Finally, it reaches the lower eyelid, at the level of which it is deflected inside to be inserted at the base of the nictitant membrane. It is understood that the contraction of the pyramidal muscle would have the effect of drawing this muscle in upon the cornea.

The quadrate muscle plays the rôle here of a tensor charged with pulling upward the tendon of the pyramidal muscle, which is equivalent to contracting the latter. Also, in restraining the tendon it prevents the latter from pressing upon the optic nerve.

The contraction of these muscles is done quickly and the attraction of the nictitant is almost instantaneous. The movement of retiring of the membrane is due to the elasticity of the joining tissue, which serves as a support for the nictitant.

The tortoise possesses a muscular apparatus, analogous, but less well developed. The quadrate muscle, much more slender and longer than in birds, is inserted by its lower end upon a portion of the posterior hemisphere of the eyeball contained between the optic nerve, the lower and the internal recti. From there it is directed upward and outward, passing over the optic nerve, and divides itself into two parts, of which one is attached to the sclerotic at the level of the external margin of the upper recti, and the other, continuing its direction of upwards and outwards, is attached at the level of the external fornix to the lower eyelid.

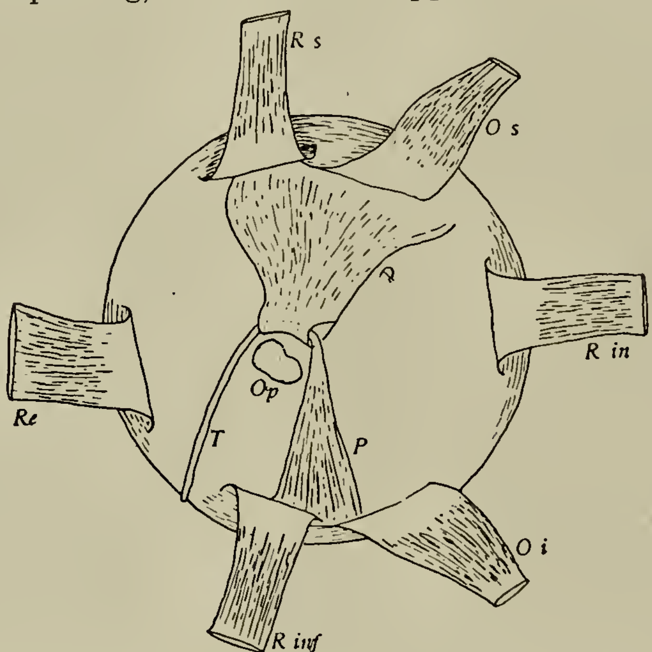
The muscular cavity included between the two surfaces of attachment of this muscle to the sclerotic, makes a passage for the pyramidal muscle. This last is inserted upon the posterior hemisphere of the

eyeball, inside of the optic nerve. From there it is directed outward, is engaged in the cavity included between the sclerotic and the quadrate, goes around the optic nerve, is directed downward to reach the external margin of the lower recti, which it follows forward to end by a short tendon at the base of the nictitant.

The groove, which the quadrate offers to the tendon of the pyramidal in Birds, is replaced here by a groove at whose level the two muscles exchange numerous anastomoses.

Like the external rectus and the retractor, the quadrate and pyramidal muscles are innervated by the sixth pair.

Generally speaking, the oculomotor apparatus of Birds' eyes is not



Posterior View of the Left Eye of the Sparrow with the Rectus Superior *(Rs)*, Interior *(R inf)*, Externus *(Re)*, Internus *(R in)*, and the Superior *(OS)* and Inferior *(Oi)*. Oblique muscles laid back to show the arrangement of the Quadratus *(Q)*, Pyramidalis *(P)* and Tendon *(T)* in relation to the Optic Nerve *(Op)*. x 8. (Wood and Slonaker.)

endowed with great power and the movements of the eyeballs are much restricted. The protective muscular apparatus is, however, highly developed.

It is interesting to compare the motor organs of the third lid in the different animals in which we have found this membrane. The most perfect motor apparatus of the third lid is in birds. Its differentiation is complete. The quadrate and pyramidal muscles are completely effective for the third lid, having no connection with a choanoid muscle (non-existent here). The combination of the two muscles allows a large surface of insertion, and in consequence, a pow-

erful action. In reptiles *(Salvator merianæ)*, the motor apparatus of the third lid is also very remarkable. We have described a large muscle, which finds its point of support no longer in the ball but in a post-orbital canal. The tendon itself is fastened by one of its extremities on the skeleton (squelette) and receives the muscular fibres of a little muscle which proceeds from the sclerotic and evidently represents the pyramidal, even as the first muscle is analogous to the quadrate muscle of birds. But we have found besides a fascia of the principal muscle which separates itself underneath its groove and is inserted to the posterior hemisphere of the globe like the choanoid muscle itself, whose rôle it fills. The differentiation is then already less marked. In the frog *(Bufo vulgaris)* the special motor apparatus of the third lid is reduced to a long tendon on which only a few muscular fibres can be found. All trace of muscular fibres disappears in the "grenouille," there only remains a tendon, a passive organ like all tendons, to which movement is communicated by the choanoid muscle. We have seen, indeed, that the choanoid muscle is so held by it that it cannot contract without stretching it. In the motor apparatus of amphibians the active rôle belongs to the choanoid muscle. The differentiation disappears more and more. In mammals we no longer find a single organ of movement belonging to the third lid. The choanoid muscle has the duty of producing at the same time the movement of retraction of the ball and the motion of the nictitating membrane.

If it is true that differentiation constitutes an element of superiority the mammals are inferior in this connection in an anatomical point of view to amphibians, to reptiles and, above all, to birds. "The choanoid muscle is so joined, in mammals, to the third lid that a constant proportion can be noticed in the development of these two organs. In solipedes and ruminants, the choanoid muscle, which is very thick, forms an almost complete funnel (entonnoir); the third lid of these animals is equally large. In animals where the choanoid muscle is reduced to a single fascia, the winking lid only covers a small part of the cornea (maki). In man and most monkeys, where the choanoid muscle does not exist, there is only found a semi-lunar fold, an entirely rudimentary vestige of the third lid. But in the two species of monkeys where we have observed a 'faisceau' of the choanoid muscle (macaque rhèsus, maimon) the caruncular crescent is more developed than in neighboring species.

The retractor muscle and the third lid are essentially organs for the protection of the eye. We have already remarked in connection with reptiles and amphibians that when these protective organs are

lacking they are replaced by others (watch crystal of ophidians, prominence of the cutaneous orbital edge, and rough [ra gueuses] of chameleons, etc.). We find the same facts in mammals. In species where the bony walls of the orbit are incomplete the choanoid muscle and the third lid are present. When the bony walls are developed, the choanoid muscle and the third lid are atrophied (lémuriens). Lastly, these organs disappear entirely in almost all pinnates, where the orbit is completely osseous.

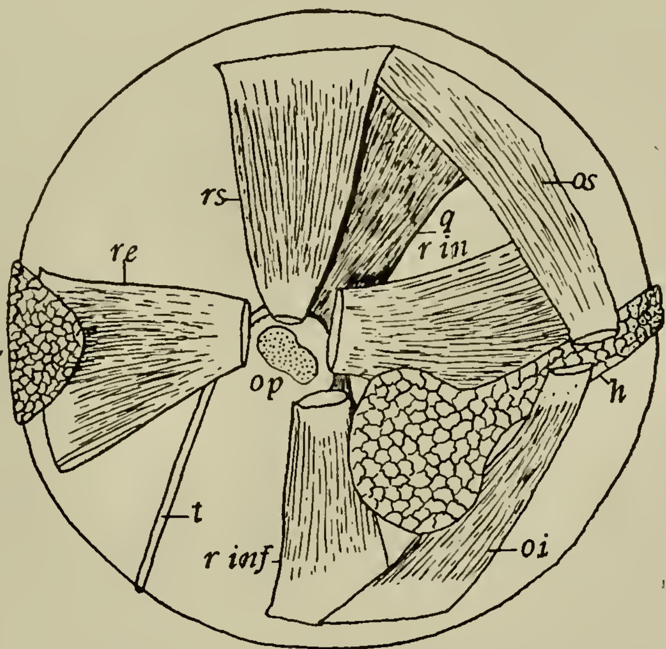
One of the purposes of the winking body, or third lid, is to keep the eye clean by removing particles which the transverse lids have allowed to impinge there; and, that which shows perfectly this purpose, is the inverse proportion which constantly exists between the development of this body and the facility which the animals possess of rubbing the eye with the anterior member (limb). Thus, in the horse and cow, whose thoracic member cannot serve this usage, the winking body is very well developed. This becomes smaller in the dog, which can use its paw to serve the purpose, still smaller in the cat, and rudimentary in the monkey and man, whose hand is perfect.'' (Lecoq: *Traité de l'exterieur du cheval.)* This ingenious hypothesis comes to support our way of seeing and is only wrong in being too exclusive. It is evident, indeed, that the third lid can sweep away foreign substances intruding on the cornea or conjunctiva; it thus becomes a means of protection against harmful particles which fall in the eye; but it first contributes, with the horizontal lids, to the prevention of these same objects from arriving on the ocular membranes, and among the causes of irritation from which it preserves the eye particularly, we may cite the too vivid direct rays of light from the sun which this semi-transparent veil softens.

Nevertheless, the choanoid muscle of mammals is not only destined to withdraw the eye to the depth of the orbit when danger threatens, but also to put in motion the third lid. All mammals which possess it to a certain degree of development are quadrupeds. Their faces, and consequently their eyes, are inclined downward in an almost permanent way. The choanoid is well located to serve as a means of suspension of the eyeball, thus leaving the recti and oblique muscles free for their action in the rotating motions of the globe. This is why the choanoid muscle of mammals is also designated as a *suspensory muscle.*

The retractor muscle of the eyeball. This muscle does not exist in Man or the Monkeys, in which the orbit is closed on the external side by a bony wall. Its highest development is reached in the lower vertebrates: Toothless animals, Rodents, Insectivora. It has a great resemblance to the recti muscles and is inserted back on the side of

the entrance of the optic nerve. Its four chief parts leave there and diverging insert upon the sclerotic in back and below the corresponding recti. Such is its disposition in the Carnivora. In Herbivora, where the retractor is particularly strong, the four parts touch each other and blend at the margins. There results a veritable enclosure whose circumference presents four strips which attach to the globe in the interval of the recti muscles. In Cretacea, the Rhinoceros, the enclosure is divided in two halves, upper and lower.

Outside of Mammifera, the retractor is not found except in the Chelonians, the Crocodilians, the Saurians, and the (Anura) Batrachia. This muscle is furnished with nerves by the external oculomotor.



Posterior View of the Left Eye of the Sparrow Showing Arrangement of Muscles and Glands. x 8. (Wood and Slonaker.)

L, Lachrymal gland; *h*, Harderian gland; *re*, rectus externus; *ri*, rectus internus; *r inf*, rectus interior; *rs*, rectus superior; *oi*, obliques inferior; *os*, obliques superior; *q*, quadratus; *t*, tendon from pyramidalis muscle to nictitating membrane; *op*, optic nerve.

Batrachia. There is no special motor apparatus for the nictitating membrane. It extends transversely below and in back of the lower eyelid, its two extremities continue on each side of the eyeball by a fibrous band bound in with the retractor muscle. The contraction of this latter would have the effect of making the nictitating membrane remount the cornea and at the same time it determines a lowering of the anterior hemisphere of the eyeball.

Mammifera. The retractor muscle is not bound in these animals to

the nictitating by a fibrous band, nevertheless, its contraction has the effect of projecting the third eyelid upwards onto the cornea.

The nictitating membrane possesses, for this effect, a cartilage whose concavity molds itself upon the portion of the globe corresponding to the internal connective cul-de-sac. By its posterior margin the cartilage plunges to a certain depth in the orbit between the ocular globe and the internal orbital partition (wall). It is also thickened at this level by the addition of padded connective tissue.

When the globe is drawn back by the retractor it throws forward the cartilage and the third eyelid covers over the cornea. The movement of retreat is due to the muscular contraction and the elasticity of the tissues.

Certain Sharks possess a third eyelid. Its movements are due to the contraction of the smooth muscles contained in the orbital membrane and in the connective membrane.

Equilibrium of the eyeball of vertebrates. As Motais (*Encyclopédie française d'Ophtalmologie,* Vol. III) points out, in Man the eye does not undergo the movement of "translation"; the only movements of the ball are those of rotation; the center of rotation is fixed and the ball is held in stable equilibrium principally by the compensating action of the retractor muscles (recti) and the protractor muscles (oblique). It could not be so in vertebrates which have no protractor muscles. The direction of the oblique muscles is indeed transverse in highly developed mammals; it becomes more and more oblique from behind forward in the inferior classes. Let us note also that in a great number of species the choanoid muscle moves the entire ball every instant. The ocular muscles being all retractor muscles, what are the agents which maintain the globe in a normal position or return it when it has been moved?

"1st. *Aponeurotic 'entonnoir' ligamentous wings; anterior orbital tendons.* We know that from the sheath of the muscles and from the fibrous capsule of the ball a fibrous sheet detaches itself in the form of an 'entonnoir,' which fastens itself to the circumference of the orbital rim. This membranous 'entonnoir' by its anterior fixed attachment opposes to a certain degree the displacement of the eye behind. It is reinforced in certain species by the wings or anterior orbital tendons.

"2nd. *The adipose or gelatinous cushion.* The semi-solid fatty mass of ruminants is a resisting point of support for the ball. It is less abundant in carnivores, but the anterior orbital tendons are, in exchange, much developed. In fish where the gelatinous mass is soft, the 'entonnoir' is relatively thick and the retractor muscle does not

exist. When the orbital cavity is large and almost devoid of filling tissue, the fibrous envelope of the ball and its 'entonnoir' have an enormous development (Sturio). In plagiostomes, where the globe floats in a cavity, the dimension of which is at least triple its size, its equilibrium is maintained in a most perfect way by the cartilaginous stem and the capsule which terminates it.

"The elasticity of the cellulo-adipose tissue of the orbit reacts at the beginning against the recession (refoulement) of the organ.

"Moreover, the fibrous 'entonnoir' contains in great number the smooth, muscular fibres (Muller, Sappey) which act in the same way. This action is much more energetic and rapid when the 'entonnoir' is reinforced by true tendons with striated fibres (carnivores).

"We observe also that the choanoid muscle exists only in vertebrates whose osseous wall is incomplete; pinnates whose orbital cavity is completely osseous have no choanoid. The osseous spaces are filled in by the '*cornet.*' This membrane is formed of fibro-elastic tissue lined with a smooth muscle and sometimes striated (orbital muscle of Gegenbauer), particularly noticeable in the Dolphin. The 'cornet' drawn back by the retraction of the eye, reacts by its elastic fibres and its smooth or striated muscular fibres pull the ball to its original position."

BLIND VERTEBRATES.

Eye of the mole—Scalops aquaticus machrinus. Slonaker (*Journal of Comparative Neurology,* Vol. XII, p. 355, 1902) has reported upon the eye of this blind vertebrate. It appears as an inconspicuous dark area, situated well forward, half way between the ear and the tip of the snout. The ocular apparatus of the American Mole is much more atrophied and degenerate in all its parts than its European congener. The most noticeable changes, when contrasted with the ordinary mammalian eye, are:

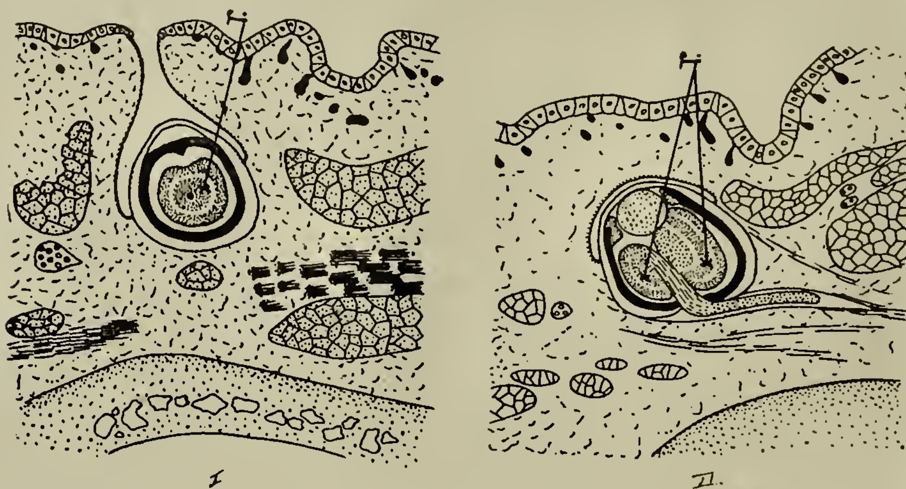
1. The fusion of the lids, thus reducing the eye cleft to a microscopic tube which is probably incapable of functioning in a normal manner.
2. The great reduction in the relative size of the eye.
3. The much crowded condition of the retina as a result of the decrease in the size of the eye as a whole.
4. The noticeable reduction in the size, or the complete absence of the aqueous and vitreous chambers.
5. The varied modification in the shape and size of the lens. Also the peculiar cell structure of the lens.

All the structures of the normal mammalian eye are present in some form or other.

The two stages of the eye which were studied, the young at birth and the adult, show a great similarity. The most noticeable difference is in the size of the eye and in the development of the retina.

The eye muscles and the optic nerve are easily traced back to the skull. At birth the nerve presents in its course from the eye to the skull a peculiar arrangement. It is composed of numerous cells and a few fibres. In the adult the nerve fibres are much more numerous.

The eye cleft as seen in cross sections shows the same diameter in both vertical and horizontal sections. It meets the eye at such an angle



Eye of the American Mole *(Scalops aquaticus machrinus)*.

cl, Eye cleft; *l*, lens; *n op*, optic nerve; *scl*, sclera; *r*, retina. The left-hand cut is a lateral, the right a median section of the same eyeball.

I, Lateral section, showing dermal orifice; r, retina; II, Vertical hemi-section, showing how the skin covers the pupillary area of the degenerate eye so that the light-rays are not focused on the central area of the retina. (After Slonaker.)

that it is impossible for rays of light, should any enter, to pass into the eye along the axis of vision.

All the elements of the normal retina are present, but, owing to the much crowded condition, the ganglion cell layer is much increased in thickness.

The lens which is found in a great variety of shapes and sizes is composed of large irregular cells with distinct nuclei. It is therefore incapable of functioning as a normal lens.

Considering the degenerate conditions which exist, it is extremely doubtful whether the eye of the mole functions in any sense. At the best it can do no more than distinguish between light and darkness.

An excellent description of the eyes of many blind vertebrates is given by Eigenmann (*Blind Vertebrates of North America,* 1908), to which the reader is referred for an account of this interesting subject.

THE EYELIDS OF VERTEBRATES.

These protective coverings of the eyeball vary greatly in the various sub-classes.

The conjunctiva of Mammals. This membrane presents habitually a velvety aspect well marked in the Steer, Sheep, Dog, and Pig; less apparent in the Cat. The tarsal connective of the Horse is often covered near the upper margin of the tarse by irritable papillæ.

The transition between the epidermis and the connective epithelium is progressive towards the base of the glands of Meibomius. The cells are shallow in the Ruminants, the Pig; nicely cylindrical in the Horse, Dog and Cat. The calciform cells are particularly abundant in the Cat and Dog. Leukocytary masses occur in the Steer, the Horse, the Pig, in the stroma of the mucosa. There are no alveolar glands of Krause, tubular alveolar of Waldeyer, nor cells described by Manz.

The elastic fibres are in great abundance in the chorion of the mucosa of the Horse, Cat, the Dog and the Steer.

Except in the Felines, there are often in the connective cul-de-sac of the Mammifera, particularly at the level of the internal angle in the Pig and the Dog, the follicular formations which may stretch to the edge of the cornea. As they are lacking in young animals, one may consider them as pathological productions.

Meibomian glands. The Mammifera alone possess glands of Meibomius. Their existence is doubtful in Birds.

The form of these glands varies according to species: tubular and very short in the Pig; in bunches in the Dog, etc. They are not always situated in the thickness of the tarsus; while in the Pig they are located in the anterior surface, surrounded by a loose connective layer.

These glands are missing in the Goat (Mountain). They are replaced by a mass of sebaceous glands contained in the lachrymal caruncle. The volume of the latter is such that it fills completely the internal angle of the orbit.

The existence of the *glands of Moll* at the level of the margin of the lids has been verified by Tartuferi in the Steer, the Cat, the Sable, the Sheep, the Dog, the Horse, the Pig, and the Bat. They are missing in the Rat, the Hare, the Rabbit, and the Dolphin.

Fishes. The palpebral organs are found in a rudimentary stage in the Selachii and appear to have only a very weak movement, although there are smooth fibres. The skin which covers them is not differentiated from the general cutaneous covering.

The bony fishes show sometimes, however, at the circumference of the globe a sort of dermal padding accompanied by several folds of

tegment near the eyeball. In certain fishes (Trigla, Serranus) the folds do not appear except at the circumference of the upper half of the eyeball. In others (Cottus, Orthogosiscus) it is lengthened around the lower half circumference. The presence of muscular fibres has never been proven.

The membrane which covers these folds has the properties of the skin and not those of a mucosa.

Among the Reptiles, the Chelonia have thick eyelids and not very mobile. The upper eyelid is generally reduced to a rigid band encroached upon by bony formations; only the lower is thin and may be displaced. In the thickness of the lids there are large lymphatic spaces, which give the organ a spongy consistency. The lower eyelid, highly developed in Lizards, possesses a fibrous tarse covered by a very thin, smooth skin. Skin and cartilage become transparent in the Slow-worm (Orvet), so that the animal can see with the lids closed. Of other Lizards, the Geckos have likewise a transparent lower eyelid, but united with the upper lid, as in Ophidia.

In the Ophidia the lower lid becomes transparent, forms a sort of shell which covers the cornea and joins by its margin with the upper lid. The shell is composed of connective tissue, continuous with the adjacent skin and of an epithelial covering; the posterior space is covered by a layer of flat epithelium.

In Batrachia (Frogs) and Birds, the upper lid is equally poorly developed; but its structure does not differ from that of the lower. The skin here is thin and supple.

The lower lid contains towards its centre, in Birds, a fibrous tarse in the form of an oval with the long axis horizontal and resembles that of Mammifera. Very apparent in Rapaceous animals and Gallinaceæ; it appears to be missing in the Parrots.

Mammifera. The lids are very mobile. In the higher representatives of the class is found a tarse analogous to that of Man; but already in the Dog the fibrous tissue, of which the tarse is formed, has lost much of its thickness.

In Man, the lids are furnished with eye-lashes on their margins. The Dog, the Pig possess, in addition, some bristles. To the eye-lashes are joined sebaceous glands and sometimes sudoriparous glands; they are missing in the Cetacea, the Cats, etc.

Outside of the Mammifera, some organs analogous to the eye-lashes are found in birds, the Ostrich, the Vulture, in the form of small feathers. These latter are often seen disseminated upon the surface of the eyelids. Inversely, in the Parrots, among others, the eyelids are completely naked.

Motor muscles of the lids. The orbicular muscle is very constant in the lids of vertebrates. It is only missing in the Sharks, the Batrachia, and the Ophidia.

In Mammifera, its circular fibres cover all the surface of the lids. It is the same in the Chameleon. Often the upper half is less well developed, or even its fibres do not reach down to the free margin of the lids.

In the Dog, the orbicularis is inserted at the level of the internal orbital wall. It is much more developed in the upper half than in the lower, and does not present a subdivision into palpebral and orbital parts.

The Right Eye of the Adult Lesser Snow Goose—*Chen hyperboreus*. About ½ natural size. (Wood and Slonaker.)

The elevator of the upper lid is represented in all Mammifera except the Cetacea. In the Herbivora, the external malar muscle (messetes) plays, in addition, the rôle of depressor of the lower lid. In the Dolphin the elevator has the form of a flat muscle which is inserted back at the circumference of the optic foramen, wraps around the eyelid in the manner of a covering, and ends in front in the substance of the two lids.

In Birds and Reptiles the elevator of the upper lid and the depressor of the lower lid constitute a group of muscles inserted at the fundus of the orbit, and because of the importance taken here by the lower eyelid, the depressor has a strength superior to that of the upper lid.

In the Batrachia (Anura) the elevator is composed of fibres which

are carried on the eyeball and fibres which terminate in the upper lid. There is no orbicular.

Eyelids of Birds. The epidermis is more horny than in man and is attached to the corium by delicate fibres.

The tarsal plate of the lower lid is undoubtedly made up of closely packed connective tissue fibres, but there are occasionally found spindle-shaped or round cells, which cannot, however, be described as cartilage cells. A delicate network of vessels surrounds the tarsal plate, and these are most marked on the outer surface.

External Eye of the African Ostrich—*Struthio camelus.* (Wood and Slonaker.)

In some birds a fatty layer, more or less marked, is found in a well-defined space between the lid edge and the upper margin of the tarsus. We have been unable to find in Passer any trace of either adipose tissue or of a space in the region mentioned.

The lid margins of the sparrow are composed of about 34 (17 each lid) deeply pigmented, irregular, sausage-like, rounded segments, often deeply indented about their middle and separated by shallow depressions; the whole presenting a picture entirely unlike the lid edges of Man. In other words, the free border of the Sparrow's lids presents when open a circle composed of a dentated cylinder set upon the lid proper.

The segments with their indentations undergo, during life, apparent

changes in size and shape evidently as the result of winking, partial or complete. Magnification of a dissecting microscope or other strong lens system shows some of these segments crossed by indentations and becoming entirely smooth again; other parts, smooth and rounded a moment before, present a creased or divided appearance, so that photographs or drawings of the eye of a sparrow give varying results so far as the margins of the lids are concerned. There is no well defined intermarginal space. A lash is placed below each palpebral segment link but the former may be missing at the outer and inner canthi, and other tufts are scattered over the lid surface. The *interpalpebral space* is 2.9 mm. wide and 4.5 mm. long.

Unless one considers the line along which the bead-like margin joins the naked skin as such, there is no *palpebral furrow* in either the upper or lower lid of the Sparrow.

There is no lachrymal caruncle or anything to indicate it, nor would one expect it if the higher vertebrate caruncle be a vestigiary remains of the nictitating membrane.

In the sparrow and other passeriformes we speak of *anterior* and *posterior* canthi.

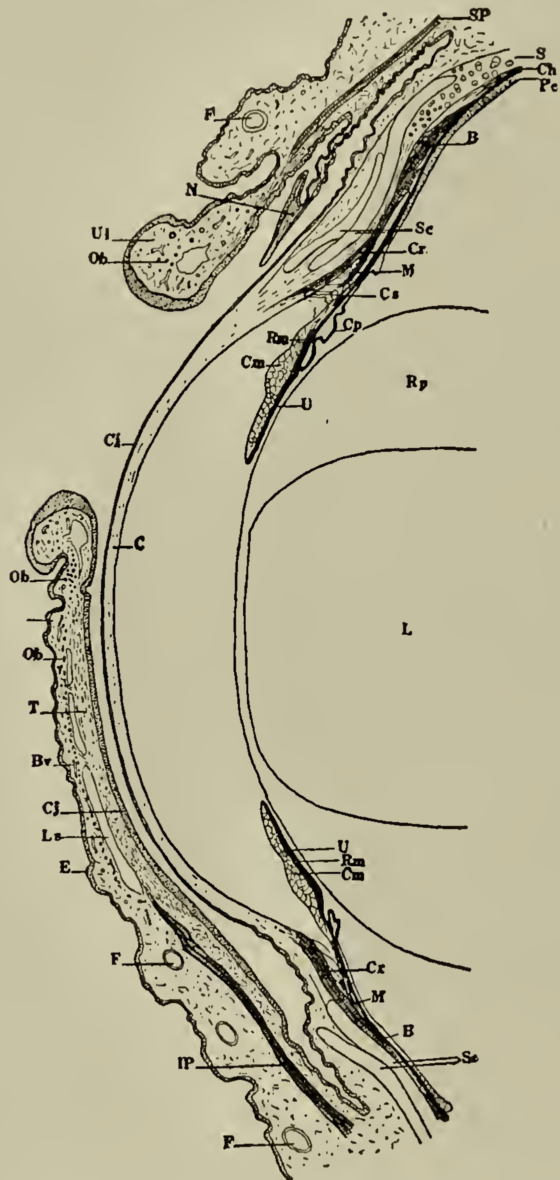
Histology. The pigment of the rounded, dark brown lid border does not extend beyond the point where it touches the eyeball, nor does it more than reach the palpebral derma. There is more pigment on the upper lid than the lower. When closed, the junction of the two lids is well above the pupil, so that the cornea is fully protected. Probably there is no upward rotation in sleep. The lower lid follows the usual law in birds, of being the movable one. It is quite thin, smooth, whitish-blue, devoid of feathers, except a few solitary shafts. Very likely there is no interference with the luminous sense and light direction sense when the eye is closed. This naked state of both lids is not seen when the eye is open, as it is then covered by the surrounding feathers.

There is no differentiated tarsus in the *upper* lid, which is much shorter and thicker than the lower one, although the convoluted cylindrical margin of the upper lid is better shown than the lower.

Eyelids of birds at birth. Unlike Man and many other Mammals, there is no true union of the conjunctivæ of the two lids before birth in Passer. In the Sparrow, as in all the Passeriformes examined by us, the lids are wide open during embryonic life, but as soon as the birdlet is hatched the eyes are closed and remain closed for several days. We have seen no evidence to prove that any organic union occurs between the lid margins in these "born-blind" birds. In all

probability the closed eyes are due to tonic contraction of the orbicularis as a light reflex act.

The *muscles of the eyelids* are the *orbicularis palpebrarum,* the



Vertical Section Through the Anterior Part of the Eye of the Adult English Sparrow. (Wood and Slonaker.)

B, Brücke's muscle; Bv, blood-vessels; C, cornea; Ch, choroid; Cj, conjunctiva; Cm, circular muscles of the iris; Cp, ciliary processes; Cr, Crampton's muscle; Cs, canal of Schlemm; E, epithelium; F, feather follicle; IP, inferior palpebral muscle; L, lenticular portion of the lens; Ll, lower lid; Ls, lymph spaces; M, Müller's muscle; N, nictitating membrane; Ob, orbicularis muscle fibres of the lid; Pc, pars ciliaris retinæ; Rm, radial muscles of the iris; Rp, ring-like pad of the lens; S, sclerotic; Scl, scleral plates; Sp, superior palpebral muscle; T, tarsus; U, uvea; Ul, upper lid.

levator palpebræ superioris, and the *depressor palpebræ inferioris.* According to Leuckart (Graefe-Saemisch, Vol. II, 1 Auf., 1876, p. 145)

and Doenecke, they are all striated muscles. Zietzschmann (Ellenberger's *Handbuch der vergl. mik. Anatomie,* I, p. 535) believes the orbicularis to be smooth muscles. The depressor of the lower lid is stronger, as one might expect from the fact that the latter is more mobile than the upper, than the levator palpebræ superioris. It is certainly attached to the lower margin of the tarsus, but it (probably) spreads over the anterior surface of the lid plate and is also attached there. Both muscles join together at their origin in the depths of the orbit, where they form part of a common muscle mass. (Slonaker had not been able to find it thus.) Slonaker agrees with Zietzschmann that the orbicularis is a smooth muscle while the depressor and levator are striated. In experimenting with the Sparrow both Slonaker and I found that the third lid is the one that closes when an object is poked near his eye and that the paired lids closed very slowly under all the stimulants we used. The physiological experiments bear out what was found by us anatomically, viz., that this muscle is controlled by the sympathetic.

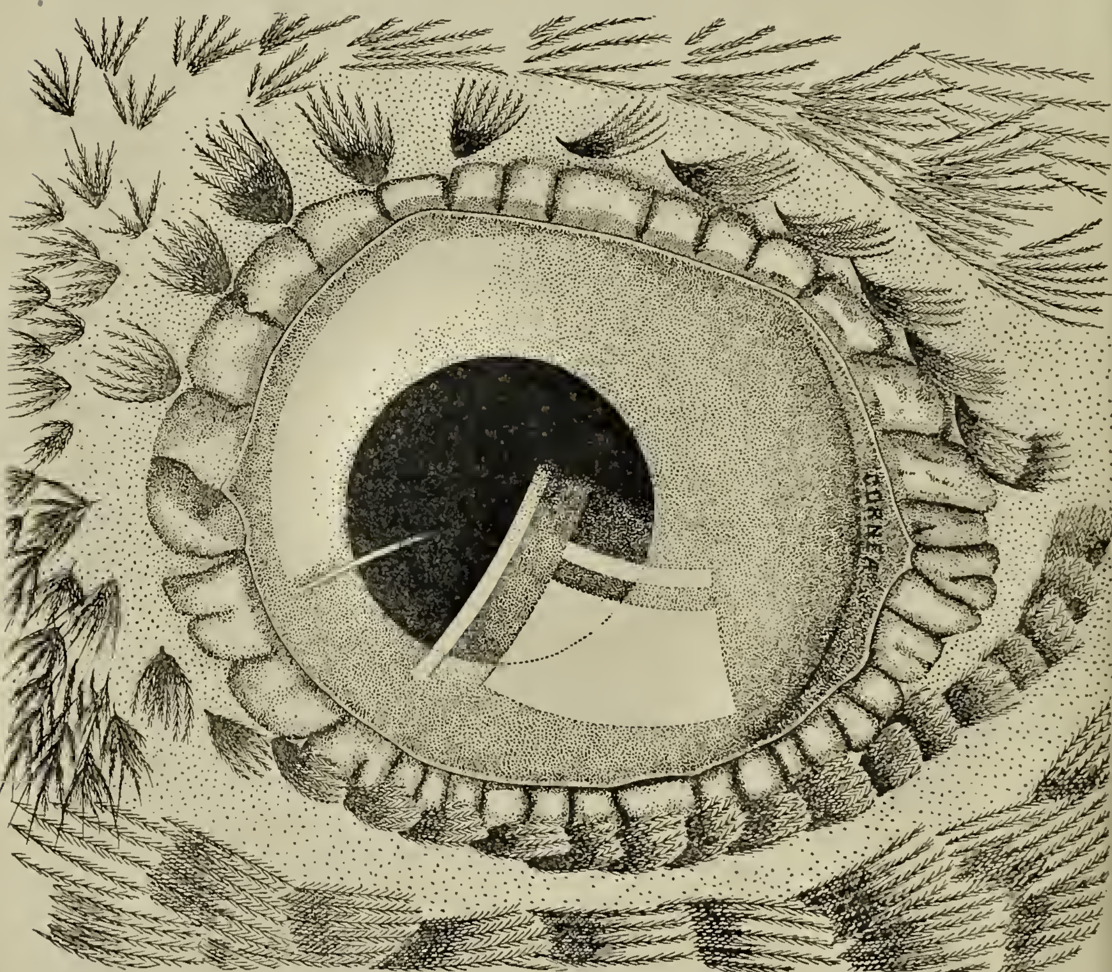
The orbicularis is an extremely thin muscle in the Sparrow, as shown in the figure. It appears as mere lines in horizontal sections and as mere dots in vertical sections. It is attached to the skin and does not, as in Man, spread out and mingle its fibres with neighboring forehead, tarsus (of the lower lid) and lachrymal apparatus muscles. There is not, so far as we could discover, any analogue of the human muscle of Riolan.

The non-striated orbicularis of Passer domesticus is probably derived from the sympathetic, although the extremely difficult problem of establishing this fact in demonstrating the cause of the fibres and determining their origin has not yet been solved by us.

Eyelashes of Birds. In the Hen the ciliary feathers more nearly resemble thick, coarse hairs, and this resemblance to vertebrate cilia is all the more pronounced in that these filiform feathers are inserted at the outer border, sometimes within the intermarginal space in several irregular rows, which at a few points interlace with the lashes of the opposing lid. Moreover, in the closed lids the inner lid margins roll in more than is the case with the Sparrow, so that the intermarginal spaces come closer together, although their entire surfaces do not touch, as in Man.

The feather eyelashes belong to the class of filoplumes or thread feathers with no true vane; the place is taken by a terminal tuft of barbs, thirty to thirty-five in number, more being found in the upper lid than in the lower. In many observations I have found the average proportion to be 17 to 14. In most instances the plumule of the tuft

rises just above the soft margin of the eyelid and is bent or directed away from the anterior canthus towards the back of the head, parallel to a line joining the two canthi. The plumules do not meet or form a screen over the palpebral margins or the interpalpebral space, as in the Ostrich or Man. In some cases the tufts are entirely wanting or are inserted irregularly some distance from the margin of the lid. At the inner canthus and especially on the lower lid the ciliary tufts are to the number of 5 or 6 directed straight forward.



Drawing from Life (much enlarged) Showing the Convoluted Margins of the Lids and the Arrangement of the Feathers Close to the Palpebral Margin. (Wood and Slonaker.)

Scattered over the two otherwise naked lids a varying number—usually half a dozen—of plumules can generally be seen of the same size as those at the lid margins. Sometimes, though rarely, they form a regular second row of cilia along the margin of the lid.

The *eyelashes* are minute tufts of incomplete feathers, and from their position relative to the lid margins do not appear to act as a

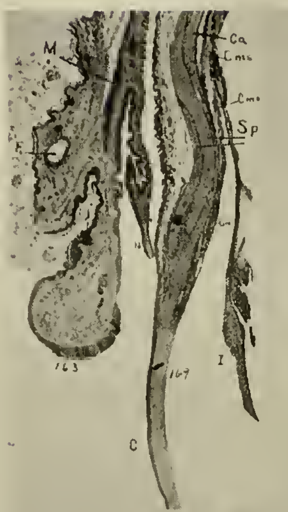
protective to the eye. They are not prominent enough for this purpose, they are too far removed from the interpalpebral space, they do not overhang the lid margin, and they do not interlock when the eye is closed, as in many of the other vertebrates. They appear in bird life to occupy a place intermediate between the Ostrich, Seriema, and other birds that possess well-developed and useful eye protectors, and the Parrots that have none at all.

The *eyelashes* of the Sparrow are rudimentary feathers without barbs, and yet more developed than in some other birds and less so than in the Ostrich, Seriema and the Birds of Prey.

Nor do the *eyelashes* take much if any part in the protection of the globe during sleep or on other occasions. The Sparrow does not entirely close his paired lids unless the cornea is touched with some such blunt object as a dissecting needle, although any approach of the object increases the number of contractions of the nictitating muscles.

Winking or lid-closure in birds. Except during sleep, or on particular emergencies, the paired lids of Birds are rarely closed. Most of the ordinary functions of the human lid are performed by the nictitating membrane. The true lids of the Sparrow may indeed be regarded as *accessory organs,* whose functions are confined to the protection and moistening of the bird's eye only while he sleeps. Wood and Slonaker have not been able to observe the Sparrow with his third lid drawn over the globe (without closure of the paired lid margins) during somnolent hours, as is said to be the case in some Birds of Prey, the Hen, etc. The soft sausage-like rolls of each lid edge approach one another and close the interpalpebral space in a fashion entirely unlike the eyes of the higher vertebrates. However, even when the edge of the third lid is incompletely drawn over the globe the edges of both lids make slight but quite apparent efforts to close, as if there were slight contractions of the marginal fibres of the orbicularis. These winking efforts are more marked when the membrane sweeps entirely over the interpalpebral space, but in this consensual contraction of the true lids we have never seen them approach their margins or reach the sclero-corneal junction.

The interpalpebral line of closure is irregular, interrupted and wavy; nor are the two intermarginal spaces accurately apposed to each other, as in Man. The Sparrow probably does not appose more than one-half his lid-margin in the act of eye-closure, but shuts off his conjunctival sac from the outside world by pressing the soft, convoluted marginate rolls into one another. The difference between lid closure in the Sparrow and most of the higher vertebrates is, roughly speaking, that between a roller-desk cover and that of a tobacco pouch.



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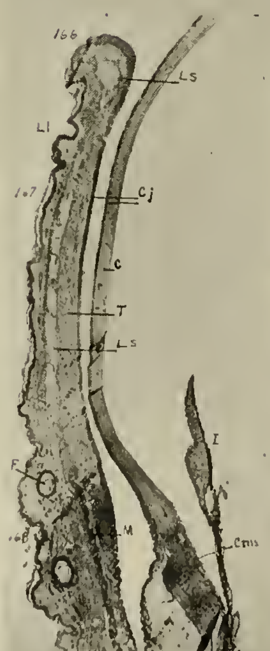

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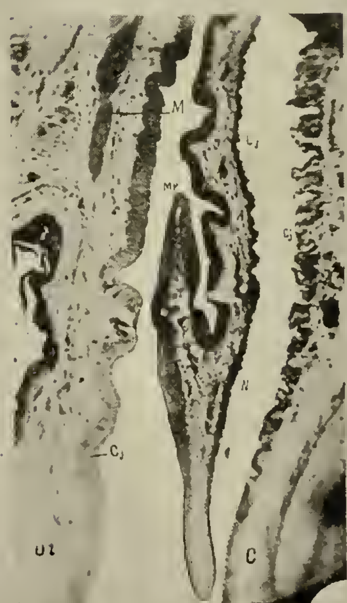

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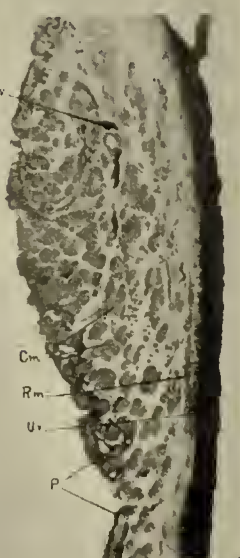

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Microphotographs of the Different Structures in the Anterior Part of the Eye, as Seen in the Vertical Section. (Wood and Slonaker.)

Bv, Blood-vessels; *C*, cornea; *Ca*, cartilage of the sclerotic; *Cj*, conjunctiva; *Cm*, circular muscles of the iris; *Cms*, ciliary muscles; *Ep*, epithelium of the lid; *F*, feather follicle; *Cl*, lower lid; *I*, iris; *Ls*, lymph space; *M*, superior and inferior levator palpabræ; *Mp*, marginal plait of the nictitating membrane; *N*, nictitating membrane; *P*, pigment in the stroma of the iris; *Rm*, radial muscles of the iris; *Sp*, scleral plates; *T*, tarsus of the lower lid; *Ul*, upper lid; *Uv*, uvea of the iris:

Fig. 160.—Low-power view of the vertical section through the lids, cornea and iris, showing the location of the enlarged figures represented by numbers. x 20.

Fig. 161.—The upper lid and related parts. x 38.

Fig. 162.—Lower lid. x 38.

Fig. 163.—Margin of the upper lid as indicated in Figs. 164-165. x 250.

Fig. 164.—Nictitating membrane and its relation to the lid and the eyeball. Owing to mark of distinction the top margin has been traced with ink. x 250.

Fig. 165.—A portion of the iris as indicated in Fig. 164, showing the circular and radial muscles, blood-vessels and pigment.

The movements of one nictitating membrane is independent of the other, although they generally act together. In an adult male, whose cornea in one eye had been irritated by manipulation, the average nictitation of five-minute observations was 55, while in the fellow eye the winking was reduced to 47. In a darkened room the number of nictitations fell to 41. The extremes we found of numerous observations under various conditions of rest, darkness, bright illumination, after flying about the room, irritating the cornea, etc., was (the lowest) 33, and during exposure to direct sunlight, 61. Under the last named condition, while the nictitating was drawn over the globe rapidly and completely, it was returned to place very slowly, so that the eye was covered by the membrane during a relatively longer period than usual.

As with most birds, the lids of the Sparrow's eye come together, i. e., the eye closes immediately, after or just before death. This, as is well known, is entirely different from Man and many other Mammalia; and the explanation is that the lid-closer is really a smooth, sphincter muscle innervated by the sympathetic, which continues to act after the departure of consciousness and after the eye-openers (innervated by striped muscles) have ceased to be under control of the will.

The *interpalpebral space* varies somewhat in the Sparrow, perhaps (although we do not positively assert this) it is a little more circular and smaller when the bird accommodates for near vision. The illustration gives an idea of the average relative size of the pupil and of the interspace during fixation for a near object.

It will also be noticed that the interpalpebral space is entirely filled by the Sparrow's cornea, a condition entirely unlike that in Mammals. In looking into the eye of Passer one sees in front the glassy cornea and behind the pupil and iris only.

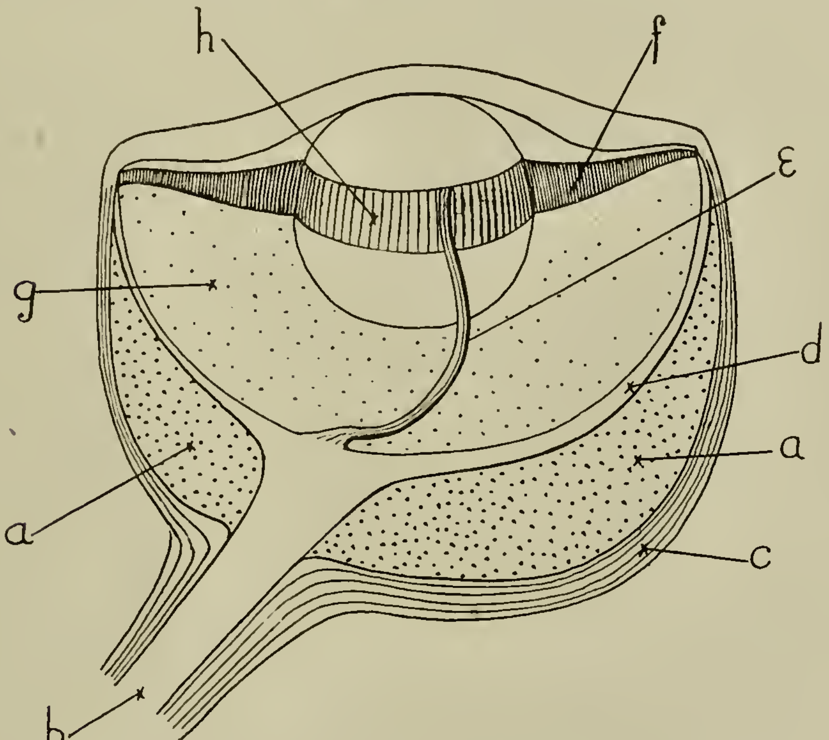
Eyelids. Sensory supply. The sensory nerve supply to the lid is entirely different from that of Man. Slonaker has found that it is from the lachrymal branch of the fifth nerve only, which after giving off branches to the lachrymal gland divides into 2 portions, one going forward into the lower lid, later to unite with the superior maxillary nerve. As yet unverified is his belief (from dissections of the parts involved) that minute branches from what he calls the *frontal* nerve (see illustration) may send sensory branches to the conjunctiva and to the skin about the external canthus.

The pecten (cone) of reptiles. The organ that corresponds to the pecten of birds assumes in reptiles the shape of a pigmented cylinder or cone, whose height equals about four times its width. This cone is applied at its base to the optic nerve. It is absent in certain Lizards—Hatteria, for instance—but is found in the Chameleon. The Iguana

exhibits two small processes that resemble the avian pecten. The structure of the cone is cavernous; in its centre is a large vessel surrounded by an envelope of capillaries. Its function in Reptiles is said to be analogous to that of the ciliary bodies.

Snakes, whose vitreous has a vascular envelope, generally lack a cone.

Crocodiles have a black fenestrated mass and Chelonians a whitish mass springing from the optic disc.



Vertical Section of the Eye of the Perch, Showing the Relations of the Processus Falciformis to the Lens. (After Leuckart.)
a, choroid gland; *b*, optic nerve; *c*, sclerotic; *d*, retina; *e*, falciform process; *f*, ciliary processes; *g*, vitreous body; *h*, annular ligament.

Falciform process in Fishes. This homologue of the pecten in Reptiles and Birds extends from the entrance of the optic nerve forward to a point just behind the iris. In this situation it rises abruptly in the form of a sharp end crowned by an extremity, generally conical, to which the name *campanula of Haller* has been given. By its free extremity the campanula is inserted upon the infero-internal part of the equatorial border of the lens. The process is colored brown or black, while the campanula is uniformly white. From the base of the process, and more or less following its axis, two vessels (a vein and an artery) run, which at the campanula divide into capillaries. These are accompanied by nerve fibres which also reach the campanula and divide into a brush of filaments.

In the tissues of the campanula one recognizes a bundle of smooth muscle fibres directed along the axis of the cone, which represents the body of a muscle. These fibres are inserted into the internal wall of the process, their other extremity being attached, by a short tendon, to the capsule of the lens at its equator. The campanular muscle should be regarded as a continuation of the tissue that covers the processus falciformis and, as in the Salmon, one notices the muscle fibres covered by the anterior extremity of the process. The function of the muscle, as pointed out by Leydig, is to retract the lens; indeed, it is the muscle of accommodation in Fishes.

The height of the *proeessus faleiformis* varies considerably. In the Acanthopterygian group it is especially short.

The histology of the falciform process then, shows it to be made up partly of connective tissue, smooth muscle fibres, nerves and blood-vessels, not to forget the vitreous tissue to which it is adherent. It may be added that the process is absent in the Selachians; the eye of these animals being of a higher order than that of Fishes.

The action of the processus falciformis, functionating as the *piseian retraetor lentis and musele of accommodation,* has been well worked out by Leydig. The muscle arises below, externally and behind the equator of the lens, and its tendon is inserted into the equator on the nasal side. When it contracts the point of insertion is drawn backwards, downwards, and towards the temple. It also causes the lens to rotate a little on its antero-posterior axis. The lens is firmly fixed by its suspensory ligament, a fibrous band that runs all around the equator and is attached to the ciliary ring at a point exactly opposite the insertion of the campanula into the lens.

UVEAL TRACT IN VERTEBRATES.

The vascular coat of the eye so liberally supplied with pigmented epithelial cells, is divided in the lower vertebrates, Fishes especially, into an anterior part, the *iris,* and, behind, the *choroid.* In the higher vertebrates there is added the circle of the ciliary body, corresponding to the sclerotic area known as the *interealary zone.* The vertebrate retina proper is limited towards the front of the eye in animals with a ciliary body by the *ora serrata;* in others it extends clear to the root of the iris.

Blood supply of the uveal traet. Most Mammals have, according to Kalt, a double arterial supply; one supplied by the internal carotid; the other (of greater volume) from the internal maxillary, a branch of the external carotid. The former supply the ciliary arteries, the latter the central artery of the retina. The *long ciliary arteries* give off numerous branches to the choroid, while the important iridian arterial

circle is supplied from the same source in those animals whose ciliary processes are situated on the posterior aspect of the iris.

In Man, the chorio-capillaris comes to an end at the ora serrata. In the lower animals with a tapetum the vessels perforate it at right angles and end in a radiating mass of capillaries.

The *venæ vorticosæ* often appear at the anterior border of the choroid. Sometimes one notices a coronet of veins (venous canal of Hovius) that reunite with the posterior vorticose veins. In the Seal there is a true canal from which there issue five large venous sinuses.

In the Rabbit the internal ophthalmic artery furnishes the long, posterior ciliary artery on the nasal side, while that on the temporal side is derived from the external ophthalmic, which also supplies a branch to the nasal areas. The short ciliary vessels largely supply the two long, posterior ciliary arteries. Just before they pierce the globe they give off from 3 to 6 principal branches that in their turn divide into 15 to 18 arterioles.

Tying the long ciliary vessels arrests all circulation in the anterior zones of the choroid and in the ciliary body. These are the terminal arteries. They furnish recurrent branches to the choroid, but they do not anastomose with the short ciliary vessels. The ciliary body and the iris receive their blood exclusively from the long posterior ciliary vessels.

In the lower vertebrates there is generally but one choroidal artery. It divides into two branches, nasal and temporal, that correspond to the long ciliary vessels. The iris is supplied by the anterior ciliary arteries.

It is much the same in Birds, that have two venæ vorticosæ. Kalt (*Encyclopédie Française d'Ophtalmologie,* III, P. 836) says that the pecten is nourished in part by the ciliary vessels and partly by the hyaloid artery.

The Frog has but a single ophthalmic artery given off within the skull by the internal carotid. It divides into two long ciliary arteries, one branch of which perforates the sclera above and the other on the external aspect of the eyeball. These run forward to the ciliary body and iris and form also the hyaloid artery. The chorio-capillaris exists only along the course of the arteries and about the optic nerve. Two veins drain the eye; the ophthalmic and the superior vein of the globe.

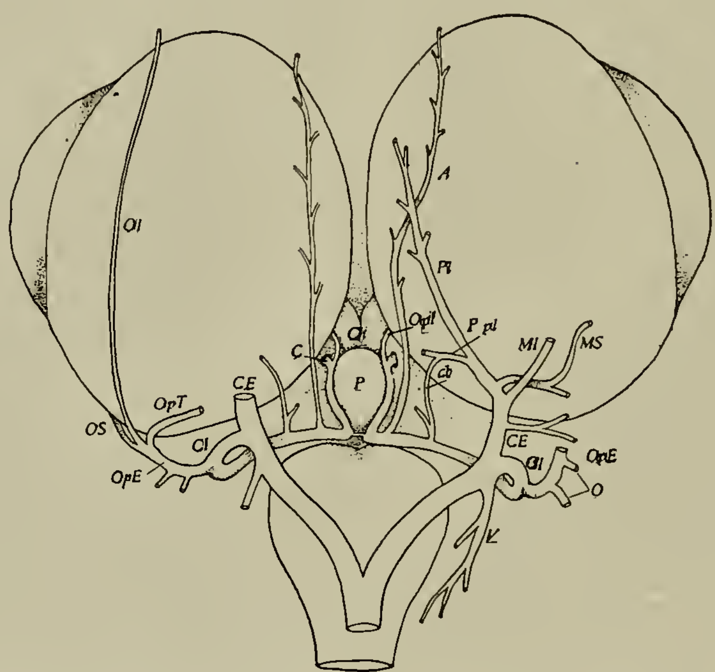
The ophthalmic artery of Reptiles divides into a temporal and a nasal branch that give short ciliary branches and the hyaloid artery.

In Fishes an external ophthalmic, or greater ophthalmic, artery supplies the choroid gland.

IRIS AND PUPIL OF VERTEBRATES.

The iris may be regarded as a continuation of the choroid. When, as in Fishes, the ciliary body is lacking this prolongation is perfect; when it is present, the iris has special characters which may, as in Birds, become quite marked. The function of the iris is in all animals practically the same as in Man.

In vertebrates the iris is composed of a connective tissue stroma coated behind by a double layer of epithelium, representing the retina, and charged with pigment. The cellular portions of the stroma iridis



View of the Ventral Aspect of the Sparrow Showing the General Arrangement of the Arteries and the Origin of Those Which Supply the Eye and its Accessory Parts. (Wood and Slonaker.)

A, Artery running forward just ventral to the capsule of Tenon, to which it sends branches; C, cerebral artery passing dorsally to the brain; *Cb*, branch connecting the posterior palatine artery of the external carotid to the internal carotid; *Ch*, chiasma; *CE*, external carotid; *CI*, internal carotid; *MI*, inferior maxillary; *MS*, superior maxillary; *O*, occipital artery to semi-circular canals; *OI*, infra-orbital; *OS*, supra-orbital; *OpE*, external ophthalmic; *OpI*, internal ophthalmic; *OpT*, ophthalmo-temporal; *P*, pituitary body; *Pl*, palatine; *P pl*, posterior palatine; *V*, vertebral.

varies greatly in amount; they are often filled with pigment, which in Felidæ is yellow.

In the Seal and Otter the dilator iridis is made up of isolated bundles of smooth muscle. The sphincter in both animals reaches

an extraordinary development, the muscle extending to the periphery of the iris. As a rule, the vessels and nerves do not penetrate the muscle tissue but are in a plexus in front of it. They are covered in front by pigmented cells and by the endothelial layer.

Kalt *(loco cit.)* thinks that striated muscular fibres constitute the principal mass of the membrane of the iris in Birds and Reptiles. They are arranged in two planes, separated by a connective tissue layer. In the anterior plane the fibres have a circular direction; they constitute the sphincter. In the posterior plane they have a radiating direction; they form the dilator. The fibres of the latter are finer than the others.

Between the two planes, circular and radiating, some oblique fibres leave the circular layers and, describing curves, enter the periphery of the iris. Several of these pass into the ciliary body.

The layer of circular fibres is particularly developed towards the periphery of the iris where it often forms an appreciable prominence on the surface of the membrane. When the animal focuses upon an object nearby, the prominence can be seen magnified and concentric wrinkles are visible. It has even been supposed that the curvature of the crystalline lens could be modified by the contraction of this portion of fibres of the iris, and that, in this way, the iris is a direct factor in accommodation.

A peculiar character of these fibres of the iris are the numerous anastomosing divisions that recall the fibres of the heart; while the dilator fibres form an exception to this rule.

The division of these fibres undergoes numerous variations. Often the posterior *radiating* layer, formed by small fibres, is missing. Among the owls the *circular* fibres are missing entirely; in their place are found capillaries surrounding groups of large adipose cells. Some reflecting cells are found in the iris of the Batrachians, as well as deposits of fatty materials, which play the same illuminating rôle. Fat occurs in the iris of Birds in the form of particles, often red or yellow, surrounded by a net-work of vessels. In general, it appears that the more luminous the medium in which the animal lives the brighter the color is. Song Birds usually have brown, Parrots and the Aquatic Birds red eyes. Sometimes the color varies with age and sex of the animal.

The iris and the ciliary body of birds receive a single ciliary nerve trunk which perforates the sclerotic outside the optic nerve and then spreads out like a fan. Eight or nine small trunks reach the insertion of the ciliary muscle where they form a circular plexus lodged in a sort of groove about the cornea. Thence a net-like web spreads over

and is supplied to the ciliary body and the iris. According to Gehberg, in the Pigeon there are few ganglion cells, especially in the region of the large branches; the small subdivisions of the ciliary body alone show a few, as do, also, the branches that accompany the vessels.

Dilator muscle of the pupil. There has been considerable disagreement among anatomists as to the characters of the muscle fibres that dilate the pupil. Generally, they are regarded as isolated bundles of smooth fibres lying in the posterior part of the stroma; in Man and other vertebrates it has been regarded as of epithelial origin.

The iris of Fishes. The anterior surface of the iris is covered by an endothelial membrane continuous with the lining of Descemet's membrane. Beneath it there is a fibrous layer, which reaches almost to the pupillary margin and is, in fact, the *annular ligament.* It is composed of a spongy tissue containing a number of cavities lined with endothelium. One may regard this ligament as the homologue of the trabecular tissue found in the iridian angle of the higher vertebrates. Behind is the *argentea* which gives the iris its brilliant white appearance. The structure of the argentine membrane is practically the same as that of the choroid.

The proper substance, or *stroma iridis,* is the thinnest of all the iridian layers. It is composed of connective tissue, numerous vessels, pigmented elements and, finally, of smooth fibres, both striated and non-striated. The *basal membrane* separates the true substance of the iris from the pigment (uveal) layer.

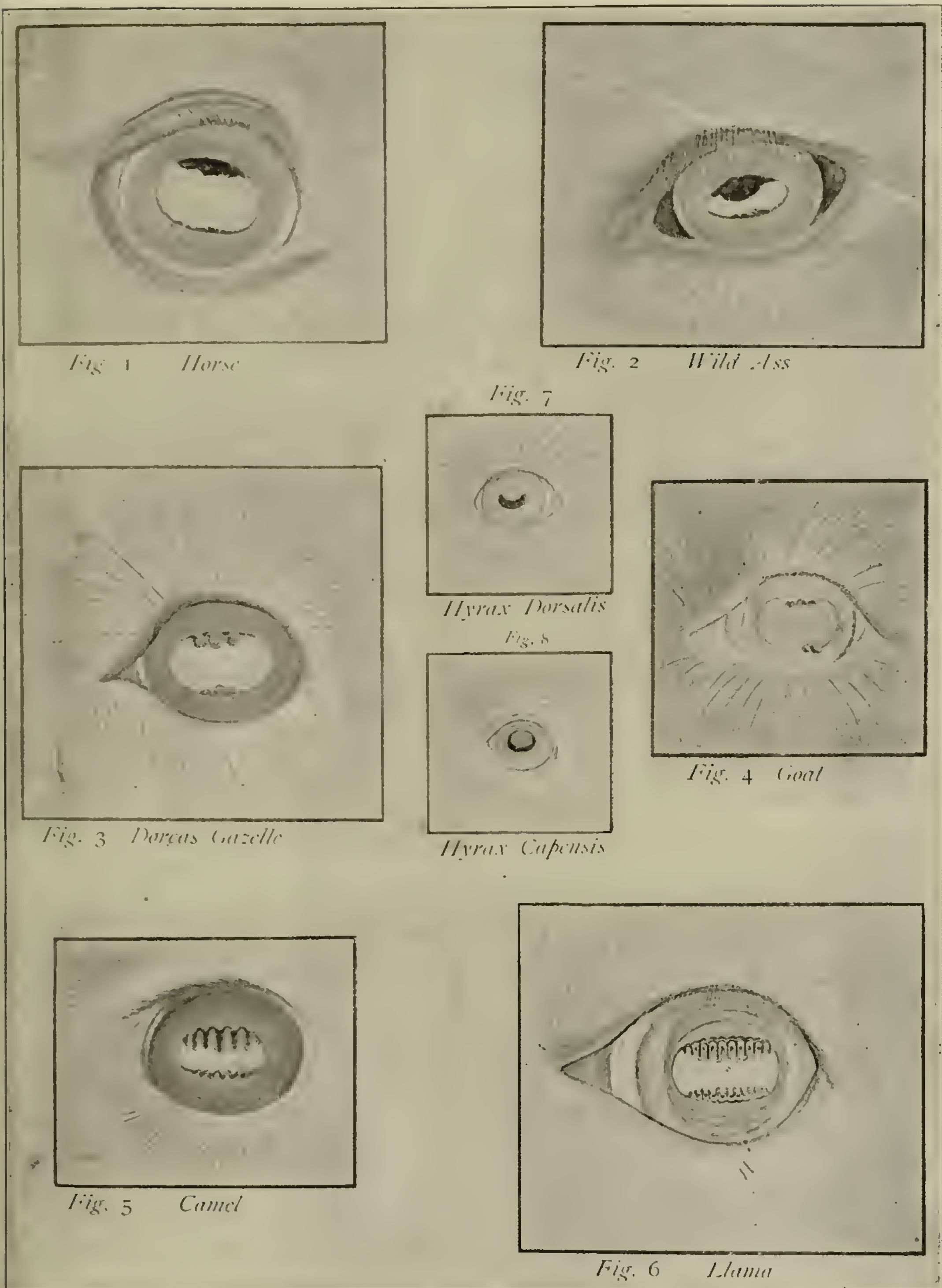
The color of the iris of Fishes may vary within a few hours, probably due to contraction of and alterations in the chromatophores already mentioned.

THE PUPIL.

This opening in the iris is not always a circle, nor does it uncover an equal area of the anterior lens capsule in all animals. In Fishes the horizontal-oval diameter is generally larger than the greatest diameter of the crystalline. In most of the Teleosteans one may easily see the margin of the lens through the pupil, the former being at least partially exposed.

The anterior surface of the iris in Fishes is uniformly plane. On the other hand, in the Felidæ and Owls the convex lens pushes the iris in front of it, so that it conforms to the curved surface of the latter.

Shape of the pupil in various animals. According to Leuckart, the pupil when fully dilated is circular in all animals and it generally retains this shape in every normal condition. In some cases, however, it assumes, on contracting, the oval form with its long axis oblique; or it may present the appearance of a vertical slit. One sees examples



Types of the Appendages to the Iris Occurring in the Ungulates, Illustrating the Successive Stages from the Corpus nigrum of the Equidæ to the Functionally Active Umbraculum in the Hyrax. (After Lindsay Johnson.)

of the former condition in the eyes of Ruminants, and the Whales, in the Marmot, the Kangaroo, etc.; the latter state is exemplified by certain Snakes, and it is also found in the Fox, the Cat tribe, and Crocodiles. All the Birds have round pupils except the Owls, whose pupils may become vertical slits, and Gallinaceous birds, who present oval orifices. In the Owls the pupil, when normally dilated, forms a vertical ellipse, but as it contracts it becomes a mere slit, thus tempering the rays of strong sunlight to the needs of this peculiar order.

The elongated pupil of the Sheep, the Horse, and the Calf, is, according to Eversbusch, due to the presence of a check ligament that can be seen as an elevation on the posterior surface of the iris, extending from the pupillary margin to the periphery.

The corneal surface is rarely a segment of an exact circle, and it has been claimed that the elongated pupillary opening of certain animals is intended to correct the resulting corneal astigmatism, but this contention is not borne out by extensive observations. Wolfskehl has shown that in the Calf, whose largest pupil axis is horizontal, in four cases out of eleven the greatest axis of corneal curvature is in the horizontal meridian.

The asymmetry of the cornea and the form of the pupil. In many animals the pupil is round but presents a more or less elongated oval form: it may be compared to a cleft rather than to a circular diaphragm. As a stenopaic slit serves to correct astigmatism, so in a large number of animals, Wolfskehl (*Zeitschr. f. vergl. Augenheilk,* I, 1882) thought, an oval pupil may correct this asymmetry. The measurements he made upon the eyes of the Cat seem to confirm this opinion.

Matthiessen has remarked that the direction of the pupil may have important relations to the habits of the animal. With the pupil elongated horizontally, as in the Herbivora, we may associate a peaceful and inoffensive nature, while in the vertically elongated pupil of Carnivores (Cat, Fox, Lynx, Owl, Crocodile, Shark), we find those that go about and with them associate the idea of stealth, cunning and ferocity. Animals with horizontal pupils, for example, the horse and cattle in the wild state, require an extensive field of view; in other words, a vertical field of vision and a pupil with a vertical long axis. Cats watch for birds in the bushes; Owls are on the lookout for mice, while the Pike, biologically and morphologically related to the crocodile, has its pupil horizontal; the field of the beasts of prey is also horizontal. The massive structure of the large Cetaceans does not permit them to turn the head, and as the field of vision of the Whale extends particularly in the horizontal with the surface of the water, it needs a pupil elongated horizontally.

In the Cat, whose pupil is a vertical oval there is a difference of 3 mm. between the horizontal and vertical meridians, the former being the greater.

The Dolphin has a heart-shaped pupil, while the Gecko, the Salamander, and the Frog have pupils shaped like an oblique lozenge.

The pupil is displaced inwards in Birds of Prey; upwards in some other animals.

Irregular pupillary forms. In Pleuronectes the superior border of the pupil is provided with a digitate process, which, when expanded, closes the opening. The pupillary membrane is controlled by special muscular fibres.

The pupillary margin in the Horse, the Narval, and many Ruminants shows, especially in the upper portion, a number of small, black masses which, although unprovided with muscular attachments, play the same rôle. Lindsay Johnson (*Contributions to the Comparative Anatomy of the Mammalian Eye,* 1901) has described and pictured these *umbracula* in his well-known atlas. (See the figure.)

Finally, in that curious South American Fish, *Anableps tetrophthalmus,* amphibious habits, the cornea (see the illustration) is barred by an opalescent, pigmented band and the pupil is divided into two equal orifices by a bridge of iridian tissue. This arrangement to which the fish is indebted for his name—"four-eyes"—as well as to the position of both globes (well above the level of the dorsum) enables the animal, as he swims along the surface of the water, both to see in air and to use his eyes in subaqueous fixation.

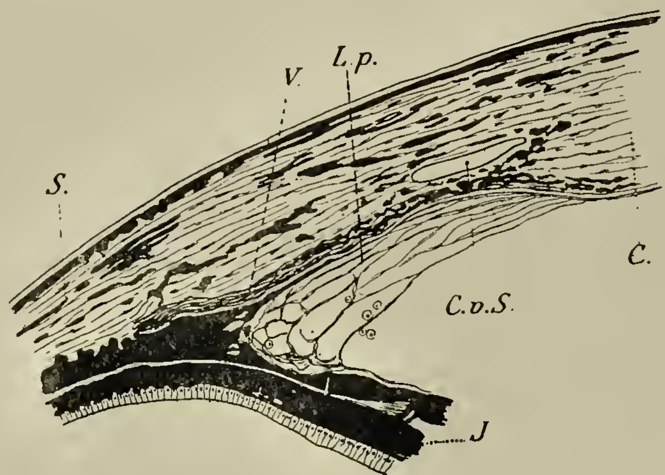
Pupillary movements in various animals. These are quite noticeable in all varieties, except Fishes, whose pupils are but slightly affected by variations in the illumination and attempts to accommodate. In them the iridic movements are extremely limited; but these differences are more marked after the animals have been kept for some time in darkness. For example, the Squids and Rays, whose pupils are expanded at night, become quite contracted when exposed to sunlight. This sluggishness to light is explained by the paucity of muscular fibres and by the encroachment of the ciliary ligament upon the surface of the iris. Beer (*Pflügers Archiv,* Vol. 58, 1894) noticed, after a subcutaneous injection of atropia, a slight increase in the size of the pupil in the Sole, Lophius and Uranoscopus. Atropine did not prevent the contraction of the pupil in the enucleated eye of Lophius, or the Frog when light was allowed to fall on it. The reflex action of the pupil to light is quite marked in Birds and Crocodiles.

The *consensual reaction* of the pupil to light is wanting in those animals in whom there is a total crossing of the optic fibres at the

chiasma; on the other hand, it is not invariably present in cases of partial crossing, as in the Rabbit.

LIGAMENTUM PECTINATUM.

In the human eye the ciliary muscle is attached to a point in the sclera about one mm. posterior to the border of Descemet's membrane. Between the point of attachment and the membrane of Descemet the ocular wall is formed, towards the anterior chamber, by a layer of trabecular tissue that is sometimes regarded as the tendon of the ciliary muscle, but which is more likely to be a modified part of the sclerotic. At the external aspect of this lamina runs, in the scleral tissue, the sinus, single or multiple, of the Canal of Schlemm.



Section of the Ciliary Region of a Snake, Showing (L*p*) the Ligamentum pectinatum. (Lauber.)

S, Sclera; V, cross section of a vein; C, cornea; C*v*S, canal of Schlemm; J, root of iris.

When examined with a lens the canal is found with its walls collapsed, so that it is not generally a complete tube.

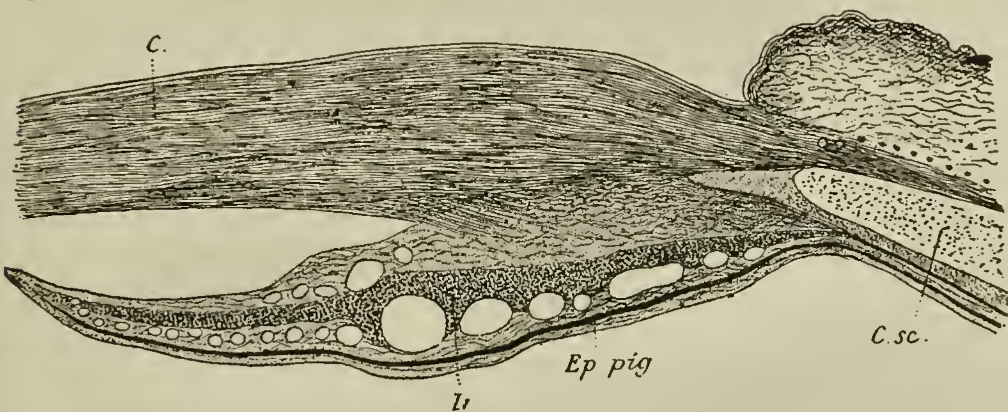
In the Horse and the Dog (Kalt, *loco cit.*) the summit of the sclero-iridian angle is crossed by a great number of parallel trabeculæ that pass from the iris to the sclerotic. Hueck has compared this organ to the teeth of a comb; hence the name, pectinate. However, behind this regular arrangement of teeth are many other fibres running in all directions. In this connection it may be said that the ciliary muscle is comparatively thinner in the lower animals than in Man, and that its connections with surrounding parts are not nearly so well defined as in Man.

The trabeculæ that fill the sclero-iridian angle are connective tissue fibres from the sclerotic coat. These fibrils pass over Descemet's membrane, from which they receive a hyaline covering provided with endothelial cells that line the posterior surface of the cornea and

the anterior aspect of the iris. These trabeculæ are generally thin and short in Solipeds and Ruminants; they diminish from before backwards and are often reduced to the merest filaments. In the Felidæ, on the other hand, they are fine but long.

The name *spaces of Fontana* is given to the trabecular lacunæ in the region just described. The human embryo at three months distinctly shows the fibrils of the ligamentum and the spaces of Fontana, but at six months they are lost through absorption of the former.

In Quadrupeds the canal of Schlemm occupies the same position as in man, but with some anatomical variations. In Birds the pectinate ligament is composed of a system of trabeculæ, elongated and spread over the internal surface of the ciliary body and root of the iris. Their plainly marked and regularly placed filaments traverse the spaces of Fontana and convert it into a true canal.



Annular Ligament of Perch. (Leuckart.)
C, Cornea; C, *sc*, cartilaginous plates in the sclera; *Ir*, iris; *Ep pig*, epithelial pigment.

The *ligamentum pectinatum of reptiles.* This is well developed both in Saurians and Snakes, and is in intimate association with a distinct canal of Schlemm and space of Fontana.

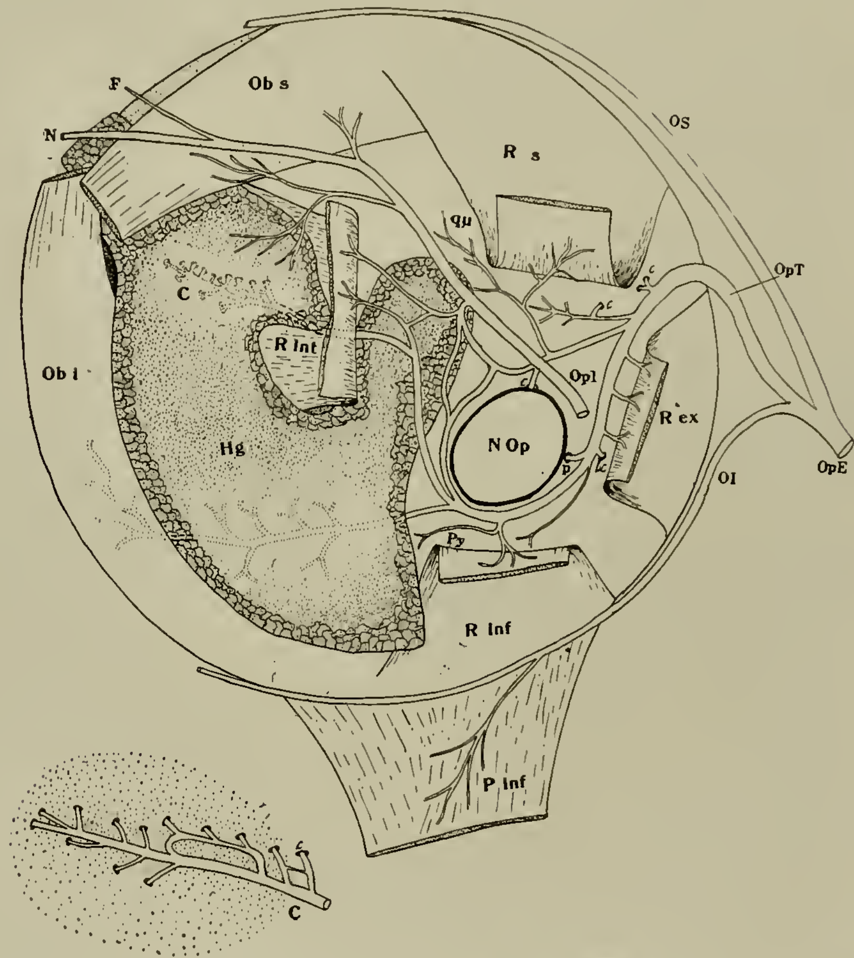
In the Frog the root of the iris is connected with the cornea by a mass formed of large ramifying and anastomosing cells. The neighboring cells of the iris are filled with pigment and are of the same character as the iridian elements of which they form a part.

The *annular ligament of Fishes* presents a fibro-spongy mass adherent to the cornea. It fills the iridian angle and is adherent by its posterior surface to the iris, which it to a large extent covers. There may also be seen in this locality towards the periphery spaces whose walls are lined with epithelial cells—an arrangement thought to be homologous with the spaces of Fontana in the higher vertebrates.

The canal of Schlemm in vertebrates. This sinus is usually single but may be divided into several canals that anastomose with one another in an irregular fashion. It may be regarded as a reservoir

accessory to the anterior ciliary veins, that carry off the blood from the ciliary muscle. There is a decided analogy between it and the sinuses of the dura mater.

The canal of Schlemm is generally well developed, though varying morphologically in Birds, Mammals, and the inferior Vertebrates. It is, for instance, of large size in the sclera of the Dog, the Rabbit, and the Ox. In Fishes it is habitually filled with blood.



Posterior View of the Right Eye of the Sparrow, Showing Arteries to the Eye and Its Accessory Parts. x 20. (Wood and Slonaker.)

C, Ciliary arteries; *F*, frontal branch of the ophthalmic artery; *Hg*, Harder's gland; *lc*, long ciliary artery; *N*, nasal branch of the ophthalmic artery; *N Op*, optic nerve; *Ob i*, inferior oblique muscle; *Ob s*, superior oblique muscle; *OI*, infra-orbital; *OS*, supra-orbital; *OpE*, external ophthalmic; *OpI*, internal ophthalmic; *OpT*, ophthalmo-temporal branch; *p*, artery to pecten; *P inf*, inferior palpebral muscle; *qu*, quadratus; *py*, pyramidalis; *R ex*, external rectus; *R inf*, inferior rectus; *R int*, internal rectus; *R s*, superior rectus.

In certain Selaceans the venous cavities of the canal are fused, so that a triangular space results, with its base presenting towards the anterior chamber. The communication with the latter is freely established by way of the trabecular tissue that constitutes its base.

The venous plexus of Schlemm's canal is uniformly arranged in

Birds. The veins of which it is composed are separated from the spaces of Fontana by a plate of endothelial, cellular, trabecular tissue whose thickness varies with the species. Between the veins are arterial twigs, portions of another plexus whose arrangement is not well known. The flow of the blood is towards the choroid.

CILIARY BODY.

That portion of the uveal tract situated in the higher vertebrates beyond the visual portion of the retina, within the *intermediate zone* the sclerotic, takes the name *ciliary body*. Here the complicated structure of the choroid is greatly simplified: the choriocapillaris has disappeared, and there remains a rather uniform vascular network

Posterior View of the Eye of the Sparrow After the Sclerotic has been Removed to Show the Larger Branches of the Ciliary Arteries and the Artery and Vein of the Pecten. x 20. (Wood and Slonaker.)

Lc, Long ciliary arteries which run forward parallel with the long ciliary nerves; *Op*, optic nerve, showing its extension obliquely downward and forward; *P*, artery to pecten; *V*, vein from pecten.

whose meshes are directed from front to rear. Inside, the boundary is formed by a vitreous membrane that supports the epithelial cells of the ciliary zone of the retina. In front, the ciliary body is attached to the sclerotic-cornea region, either by simple adherence, as in the Fish, or by help of the pectinate ligament. Reduced to this degree of simplicity, the median portion of the uveal tract is found in the majority of Fishes, some Amphibians (Tritons) and in the Ophidians.

Ciliary processes. As Kalt *(loco cit.)* remarks, early in the vertebrate life of Sharks and the Sturgeon, there appears a system of folds, an outline of the ciliary process, directed from front to rear, jutting out towards the interior of the eye. They are very numerous, several hundreds having been counted; and although their elevation is at first very slight yet in certain sharks their apices reach the equator of the crystalline lens. All have not the same height, however, and they are often partially united with their neighbors. In the Tunny-fish, the only Teleostean which possesses ciliary processes, the latter have an unequal development and do not come into contact with the lens.

In Amphibians and Saurians, the ciliary processes remain rudimentary with the exception, however, of the Crocodile, in which they touch the crystalline. The Frog shows antero-posterior folds, 70 to 80 in number, that extend to the posterior surface of the iris. In the Chameleon and in the Tortoises it is difficult to distinguish an outline of the folds.

In Birds, the ciliary processes attain a very high degree of development. The folds, several hundred in number, cover the internal surface of the intercalary segment, while their free borders are imprinted on the periphery of the lens, where they sometimes form a veritable collar, as is seen especially in the nocturnal birds of prey. In them, as in the Shark, the height of the processes is variable and many present an ill-defined outline. Each process has two vessels, one of which runs along near the free edge, the other follows its base; communicating branches unite them.

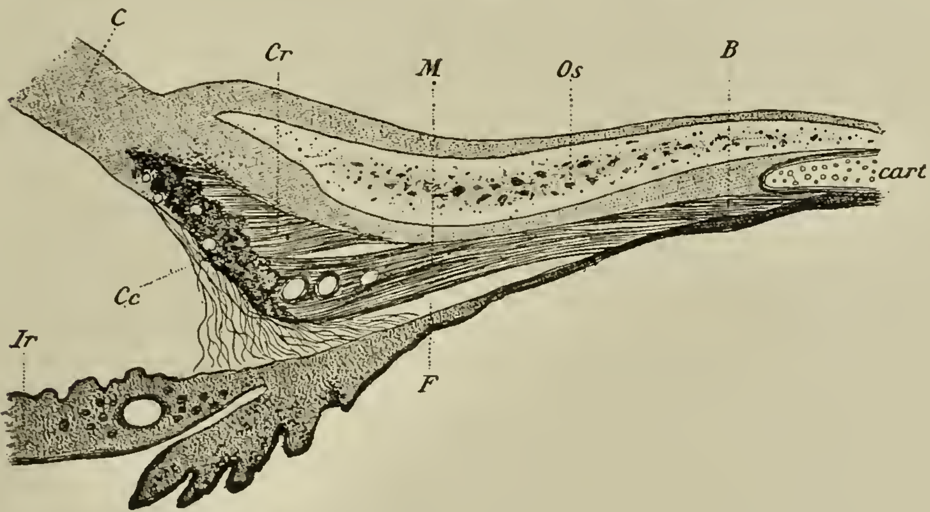
In Mammals the ciliary processes come in contact with the periphery of the crystalline. There are generally not more than 70 although this figure is surpassed in the seal. Between the true folds, however, there is often a series of folds of analogous structure, although smaller. The heads of the ciliary processes in the Herbivora bear at their free ends a series of plicatures and notches, each containing a vascular ball. The secondary folds are highly developed in this order.

In the Rabbit, Guinea-pig, Dog, Cat and Kangaroo Virchow has described a sort of ring, which unites transversely the folds of the ciliary body and forms an annular projection towards the equator.

Epithelium of the ciliary body. This is a continuation behind with the two layers of the retina. Its external layer is pigmented: the internal layer is formed by cells cylindrical behind, cubic in front. The internal layer is not deeply pigmented until the root of the iris is reached. In the Rabbit the pigmentation of the internal layer appears at the head of the ciliary processes, and all the processes that arise from the posterior surface of the iris show the same aspect.

Between the cylindrical cells of the non-plicated portion of the ciliary body are found fibres which arise from the elastic (choroidal) lamina. These fibres are directed towards the equator of the crystalline lens. They constitute the suspensory ligament of the lens and reinforce the anterior portion of the hyaloid membrane with which it has intimate connection.

The wealth of vessels in the ciliary processes leads us to the supposition that the ciliary body serves not merely as an attachment of the lens, but that it supplies nutrition to the vitreous body and the crystalline. This hypothesis is supported by the fact that ciliary processes are lacking in those animals provided with an hyaloid vascular system, as in Fishes and Reptiles. The processes reduced to



Section of the Eye of the Turkey Cock. (Leuckardt.)

F, Spaces of Fontana with trabeculæ; *Os*, bony plate; *cart*, cartilage; *C*, cornea; *Cc*, line of insertion of Crampton's muscle; *Ir*, iris and ciliary body; *Cr*, Crampton's muscle; *M*, Müller's muscle; *B*, Brücke's muscle.

the condition of single folds cannot be considered as vascular organs. Also, there is a correlation between the mass of the ciliary processes and the volume of the eyeball. For these reasons one may admit that the ciliary processes represent, above all, an organ of nutrition so arranged that its vascular surfaces have the largest possible exposure to the parts it is intended to supply.

Ciliary muscle. Apart from the ciliary processes, the mass of the ciliary body is formed by the ciliary muscle. In man, we know that it has in a section the form of a half-open fan whose handle represents the pectinal ligament and whose margin is directed inwards and to the rear.

The most external muscular laminæ are prolonged, behind, in the connective lamina of the supra-choroid. With its two posterior and

anterior insertions *fixed* the muscle may be compared to the muscle of Crampton of Birds.

The laminæ next in order separate into fan-like rays and are lost on the connective lamina of the ciliary body in the direction of the choroid. After first taking an antero-posterior direction, the fibres then turn and assume a circular direction. The fibres nearest the anterior margin of the ciliary body take almost identically the same direction. In the internal and anterior angle are found wholly circular fibres (muscle of Müller).

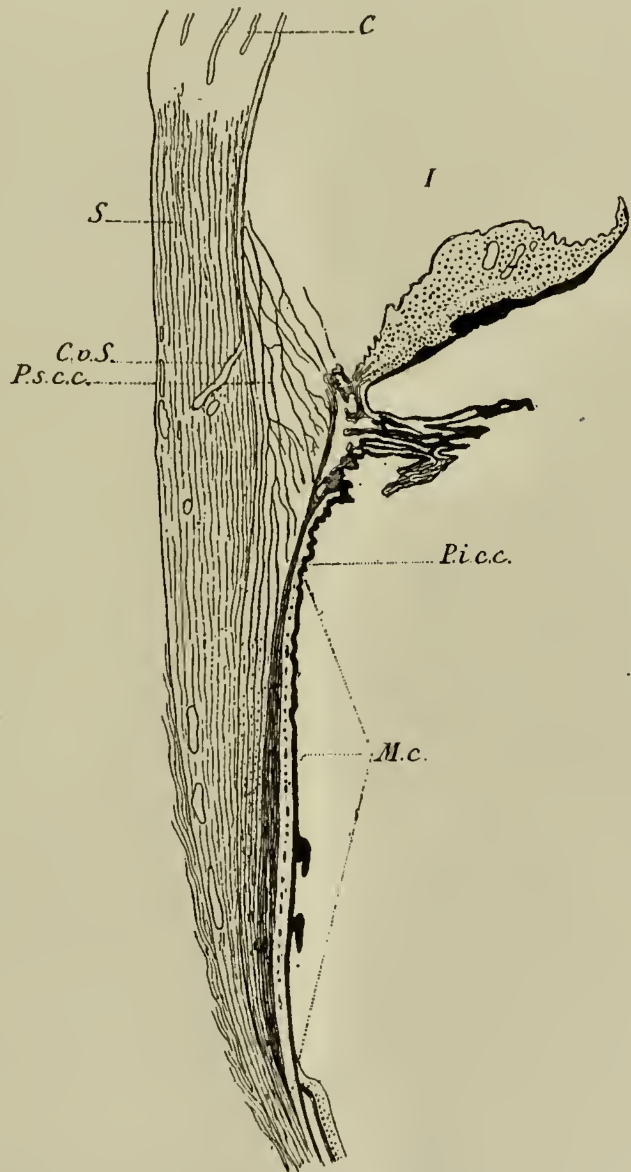
The iris in vertebrates may be considered an anterior prolongation of the connective tissue lamina of the ciliary body, which serves as a support for the ciliary processes.

Varieties of form in the ciliary body. In Man, the ciliary body is composed of a connective lamina which supports, on the outside, the ciliary muscle with its longitudinal, oblique and circular fibres; on the inside, the ciliary processes. Muscle and process are intimately united, while from the anterior aspect the iris is detached. The latter appears in reality to be the continuation of the mesodermal lamina interposed between the muscle and the process. This is true, also, among Monkeys. As the muscle thins out, a slit-like area divided into numerous trabeculæ shows itself between the muscle and the ciliary processes. These latter are the spaces of Fontana. Consequently we may regard the ciliary body as divided into two portions: an external, scleral, and an internal portion which continues forward into the iris. This division of the ciliary body into two distinct parts is especially marked in Birds and in the Alligator. The interval referred to extends very far back, tapering out to the point where the muscle meets the external surface of the ciliary body. In the Hen this point is situated nearly half way between the canal of Schlemm and the ora serrata. The anterior opening of the slit (into the anterior chamber) is traversed by long, slender trabeculæ, which are attached both to the iridian root and to that portion of the ciliary body next to the corneo-sclerotic wall as well as to the fenestrated membrane which forms the internal wall of the canal of Schlemm.

Variations in form and structure of the ciliary muscle. This subject is fully treated in the *Encyclopédie frs. d'Ophtalmologie,* Vol. II. The further one descends in the animal scale from Man and the Monkeys the greater the reduction in the volume of the ciliary body. In the higher monkeys the longitudinal fibres and their circular faschia are well marked; the mass of the muscle is especially marked by the presence of abundant pigmentary cells which are found both in the Prosimians and in all the Mammifera. Here the anterior extremity of the muscle thins out, while the circular fibres, at the internal angle

of the ciliary body are missing. Between the muscle and the ciliary processes is introduced the areolar mass, just described, which bounds the space of Fontana.

The Carnivora are next in order and present a ciliary muscle which sometimes extends, as in the Cat and the Lion, posteriorly to the ora serrata, while in front it reaches the root of the iris. (See the illustration.)

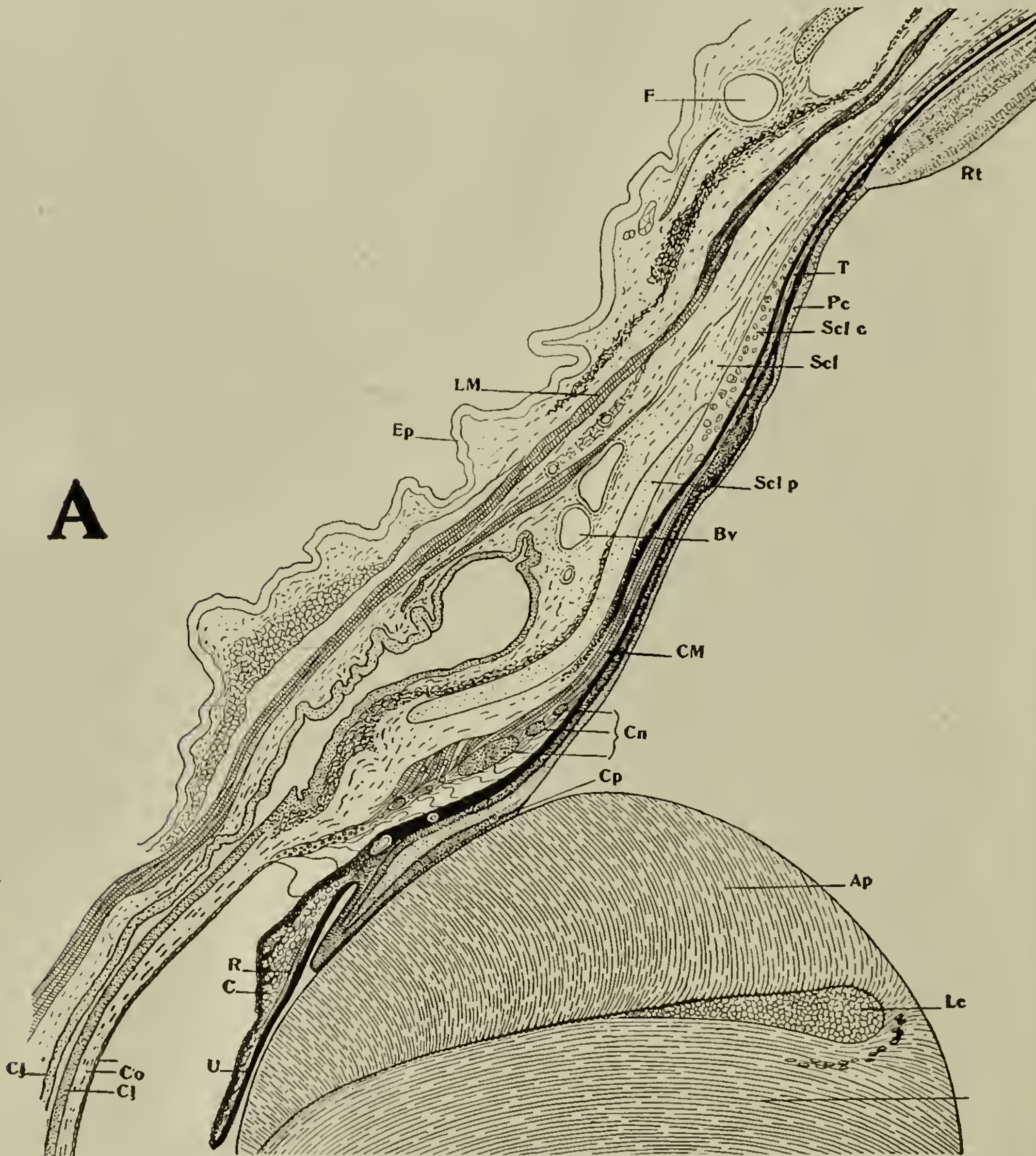


Section of the Ciliary Region of the Cat. (Lauber.)
C, Cornea; *S*, sclera; *CvS*, canal of Schlemm; *Pscc*, scleral division of the ciliary body; *Mc*, ciliary muscle; *I*, iris. The ciliary muscle is depicted as reaching as far backward as the ora serrata.

Würdinger (*Zeitschr. f. vergleich. Augenheilk.*, 1886) has described the extraordinary development of this in the Otter, an animal which

pursues its prey both on land and under water and which consequently requires a powerful accommodating apparatus.

The reduction in size of the ciliary muscle referred to shows to advantage in Bats and Rodents. The ciliary muscle of the Rabbit is a case in point; its fibres are very poorly developed.



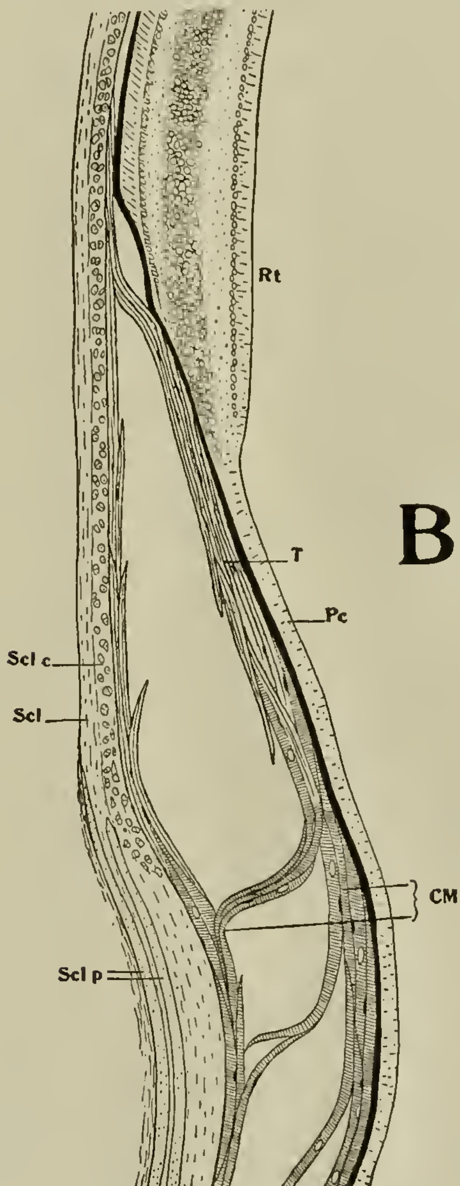
B, Enlarged Drawing from a Section of the Sparrow's Eye, Showing the Posterior Portion of the Ciliary Muscle and its Posterior Tendinous Continuation and Attachment. (Wood and Slonaker.) (See also next illustration.)

In the Horse, Pig, Sheep, and Ox, the ciliary body has a marked development; on the other hand, the ciliary *muscle* is very weak in most members of this group.

Among Cetaceans, the Dolphin, according to Lauber, lacks the muscular elements of the ciliary body, while very few are found in the Edentata and the Marsupials.

One often finds at the posterior termination of the ciliary body, in the place left empty by an undeveloped muscle, layer of large cells continuous behind with the endothelial cells of the choroid.

The *ciliary muscle of Birds* reaches considerable development. In the birds of prey it is, however, much more marked than in the other orders.



CM, Ciliary muscles; Pc, pars ciliaris retinæ; Rt, retina; Scl, sclerotic; Scl c, scleral cartilage; Scl p, scleral plates; T, posterior tendon of the ciliary muscles attached to the sclerotic posterior to the ora serrata.

Reptiles possess a ciliary muscle composed of striated fibres analogous to those of the bird, but much less developed. Their insertion takes place, as a rule, well in front, generally at the internal margin of the cornea, or upon a special lamina attached to its margin.

The highly developed ciliary body of the Alligator is divided into an internal portion, including the iris, and an external portion, formed principally by the muscle of Müller. The Cramptonian portion lies deep in the sclerotic tissues while serial sections demonstrate marked variations in the proportions of the muscle bundles. Their two other muscular portions are present in the same proportion and give the whole muscle the appearance seen in birds of prey.

The *pectinate ligament,* which binds the iris to the sclerotic, resembles that in Birds.

Batrachia. The *ciliary muscle in Batrachians* may exist, as in the Frog, in the form of a tensor of the choroid (Virchow); but its existence has been denied (Lauber). It is absent in the Fishes.

The *ciliary, meridional, striped muscle of accommodation* is well developed in Birds. According to Slonaker, Zietzschmann and von Pfugk, it is generally divided into three parts—Crampton's, Müller's and Brücke's—the first serving to constrict the globe, Müller's muscle being supplied to the iris and Brücke's to the *pars ciliaris retinæ,* and probably to drag forward the choroid in accommodation. Slonaker and the writer find the description of this region as given by Zietzschmann and Gadow to be correct so far as the Sparrow is concerned.

It is also in agreement with Canfield and Exner who believe that it matters little whether one regards the ciliary muscle in Birds as a unity or a trinity, except that, anatomically, there is often no definite division into the three parts above mentioned. Physiologically they are *one,* and contract and relax at one and the same time.

Altogether the observations of Leuckart (Graefe-Saemisch *Handbuch der ges. Augenheilk.,* 1st Edition, Volume Two, p. 145) agree with those of the writer, viz., that Brücke's muscle is the analogue of the ciliary muscle in Man, and lies farthest back of the three divisions. It stretches between the orbiculus and choroid, on the one hand, and the sclera on the other. As in Mammals, it probably acts as a *tensor choroideæ.* The most external muscle, Crampton's, fills the space between the border and the inner wall of the sclera at the anterior margin of the sclerotic ring. Internal to this muscle is inserted Müller's portion, which is joined to the orbiculus or pars ciliaris retinæ. All these muscles lie more or less behind one another. (See the figures.)

The writer is, with Slonaker, not competent as yet (from exact dissection) to speak definitely on the nerve supply to the muscles of the ciliary region in Birds, so that opinions on that point set forth here are those of other authorities.

There are about 78 ciliary processes in the Sparrow and their intimate connection with the upper aspect of the lenticular "Ringwulst" may easily be proved by the use of the binocular microscope.

It is difficult to say just what constitutes the *zonula ciliaris* in the Bird. Slonaker and the writer believe, from an (as yet incomplete) examination of this matter, that numerous fibrils not only join the ciliary body to the lenticular capsule both anteriorly and posteriorly, but *form with the filaments of the vitreous framework a complete union of the "Ringwulst," ciliary ring and vitreous.* In other words, the ciliary processes, lens-ring and an anterior segment of the vitreous are all bound together by a filiform network, so that they move, or are moved, as one coherent mass. This intimate union of these organs is all the more evident when the area of capsulo-ciliary attachment is examined. If the ciliary processes are, in fresh eyes, torn from the equator of the lens-ring the contact areas of the two are distinctly outlined by the pigment that continues to adhere to the lenticular capsule, so that the number of processes touching the lens can easily be counted. There must, therefore, be an intimate, organic union and not mere contact between them. This fact is, of course, of great importance in considering the method of accommodation in Birds.

CHOROID.

This membrane is united to the sclera by the connective tract of the *suprachoroidea.* The serous space between these, whose existence Schwalbe demonstrated, is replaced in Birds by a true lymph cavity having smooth and opposed walls.

Quantities of *pigmented elements* are deposited along the course of the larger vessels of the choroid. Between them are found in Teleostean Fishes a special pigment deposit furnishing a glittering white reflection and called the *argentea,* or *argentine membrane.* The argentea gives the impression that one had cut into the sclerotic of a bony Fish.

This membrane contains, like the cutaneous and peritoneal coverings of the same animals, an infinite number of guanine crystals in the form of long plaques, united in parallel or oblique bundles. These crystals appear to be set in the bodies of the cellular elements.

This *tunica argentina,* quite hard and rigid, stretches forwards to the pupillary border of the iris. In the latter situation it is thicker than the choroidal portion and as the iris is not covered in front by a large amount of pigment it gives to the piscian iris the brilliant silvery appearance so familiar to us.

The internal aspect of this brilliant, white tunic is covered, as before stated, by a layer of large choroidal vessels interspersed with

pigment cells. The latter are disposed, even in Fishes provided with an *argentea,* in the shape of hexagonal plates, or in a more irregular form. Consequently, the argentea cannot be a light reflector or act as a *tapetum.*

The tapetum. This is a reflecting layer placed between the large vessel layer of the choroid and the chorio-capillaris. Among Fishes, we find it in the Rays, the Sturgeon, and some Teleosteans. Kalt says that it is not found in the choroid of Amphibia and most Birds, but is present in a large number of Mammalia, Carnivora, Ruminants; in the Horse, Elephant, and the Carnivorous Cetaceæ. In the Seal, the Dolphin, the Cetaceæ, and the Fishes this layer covers the whole ocular fundus but does not extend forward beyond the region corresponding to the ciliary body. On the other hand, in most Mammalia it is limited to a single fundus area, above and external to the optic entrance, the seat of monocular and, when it exists, of binocular vision.

The *tapetum of Fishes* presents the same structure as the *argentea.* Crystals of guanine are deposited within large, nucleated cells, arranged between the chorio-capillaris and the large-vessel layer of the choroid.

The *tapetum of Mammals* has not such a brilliant sheen nor does it contain as much organic crystalline matter, as the piscine argentea. There are two forms of the mammalian tapetum. each with quite different anatomical characters.

In the Carnivora and the Seals the tapetum is composed of cells smaller than those found in Fishes. They assume the arrangement of elongated plates, which produce the phenomenon of light interference. The cellular elements of the tapetum are in direct contact with the endothelial layer that covers the chorio-capillaris. In the Dog and the Cat there are 5 or 6 layers, whose combined thickness is 20 microns. These elements form very thin layers and their outlines are hexagonal or are quite irregular in shape. The cell contents are granular, and, to transmitted light, yellowish in color; the nucleus measures from 5 to 6 microns. Under a high power these cells lose their granular appearance and are seen as an infinite number of acicular crystals arrayed in parallel fashion and in groups. These crystals are bi-refractive, and their composition has not yet been determined.

Sometimes chalky-white deposits are found in the tapetum of Carnivora.

Apart from those Carnivores whose tapetum is *cellular,* the other Mammalia, the Dolphins, and the carnivorous Oppossums have a *fibrous* tapetum. The component fibres present a crucial arrangement

as compared with the layer vessels of the choroid. They have an undulating appearance, and are very delicate.

The tapetum is absent in Birds, although the Ostrich has a glass-like layer in the choroid of lamellated structure capable of reflecting light and producing color interference effects. This arrangement, however, is only a retino-choroidal variation, and not a true tapetum.

It has been claimed that the *function of the tapetum* is to reflect rays of light that have already acted on and passed through the retina by making them once more traverse the same road, but inversely. By this economy of light animals supplied with a tapetum are able to perceive objects that are but feebly illuminated. An objection to this theory is that many nocturnal animals are not provided with a tapetum.

Among these may be mentioned the Owls, Bats, Squirrels, and the lower Monkeys. On the other hand, the presence of a tapetum is no bar to vision in bright daylight. Animals with a tapetum are all supplied with a most active iris and are able to regulate at will the supply of light admitted to the interior of the eye. Moreover, the rays reflected by the tapetum against the walls of the ocular interior are mostly absorbed by the abundant pigment deposits of the ciliary body and posterior surface of the iris.

The avian choroid. The thickness of this coat is about 200 microns. The vessels of the *chorio-capillaris* measure from 10 to 20 microns in width; between them is a finely punctate substance. This layer is 7 to 8 microns thick. Externally there is an endothelial layer, then a net work of fine elastic fibres without cells or pigment; finally, a dense plexus of connecting cells.

The *nerves* run within the suprachoroidal space and send only fine filaments into trabeculæ that form a cavernous system throughout the whole coat.

Striated *muscle fibres* form a network of meshes which are found only in the suprachoroidea.

The choroid gland in Fishes. According to Virchow this vascular, reservoir-like organ is an annular or horseshoe-shaped, reddish, spongy body, situated in the substance of the choroid between the *argentea* and the pigment layer. Sometimes it is comparatively small, at others several millimeters in thickness. It is found in the Bony Fishes, is highly developed in Amia (the Mud Fish), but is absent in Muraena, the Silurians, and the Ganoid Fishes.

The organ is supplied by and largely composed of small, paired vessels (the one arterial, the other venous) lying close together. The arterioles are derived from branches of the external ophthalmic artery, while the veins pour their blood into a large reservoir situated at the base of the gland. This reservoir at the same time empties, along

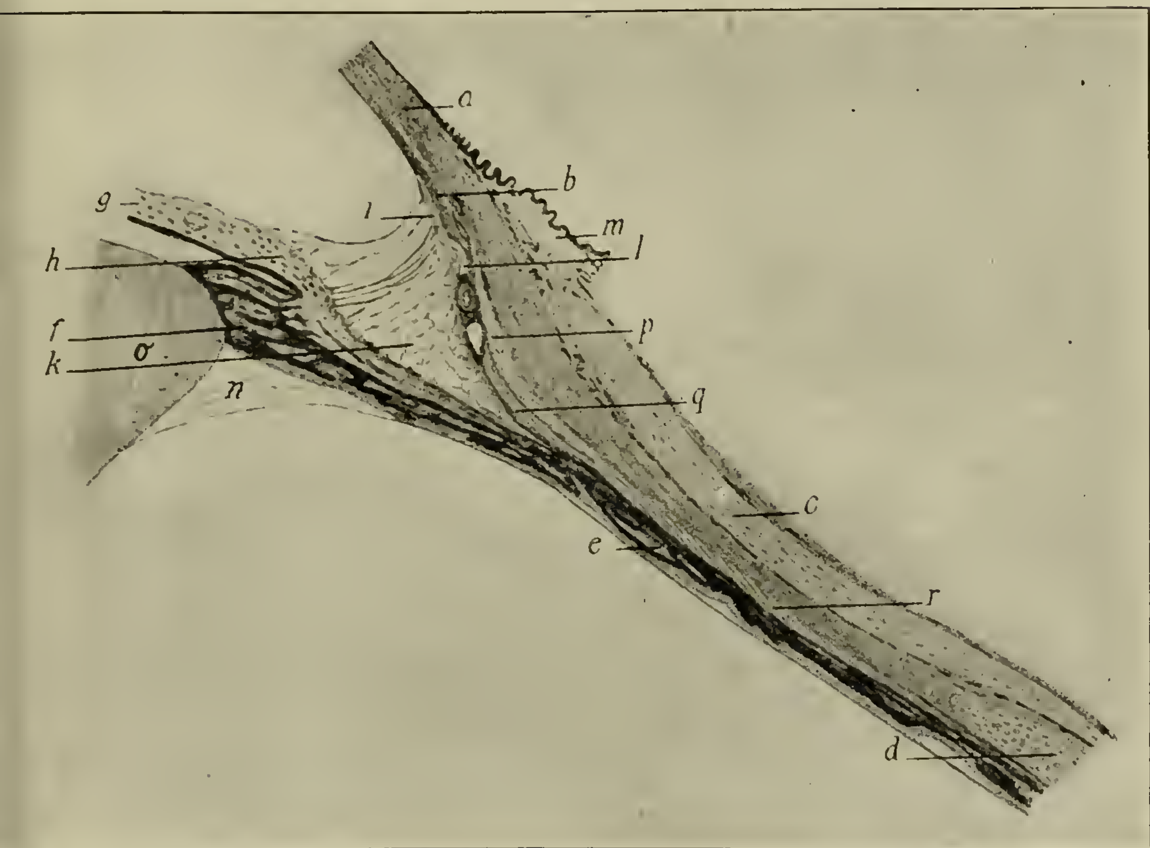
with the venules from the iris, the muscles and the optic nerve into the ophthalmic vein, a branch of the jugular. The two vascular systems of the gland communicate with one another by large choroidal vessels and by way of the chorio-capillaris. Kalt found the choroid gland of the Pike to measure 2 mm. in thickness.

Uveal tract in Birds. There are several subjects under this heading that call for a separate report and, in some cases, discussion. Hess (Supplement XV of the *Zoologisches Jahrbuch,* Vol. III, p. 155) found in day birds—Hen, Moor-Hen, Pigeon, Sparrow and Kite—a direct opening between the anterior and vitreous chambers, which, he believes, permits a free communication between these two spaces and insures an equalization of intraocular pressure during active accommodation. He injected into the anterior chamber of the freshly enucleated eye in each case, first fluorescein, and afterwards milk, and on each occasion noticed that a small drop of the fluid oozed through a small opening situated about the centre of the ciliary ring downwards, towards the pecten. The exact situation of this opening, as shown in the illustration, corresponds to the optic cleft. Hess was unable to establish the existence of this opening in the ciliary ring of Night Birds, although the same experiment was made on a number of Owls. Slonaker and the writer have not so far been able either to substantiate or disprove this plausible theory.

Ligamentum pectinatum iridis of Birds. The angle formed by the cornea and iris is occupied by well-marked, extensive open-work tissue. In the Sparrow the pectinate ligament lies in the space bounded by the iris and ciliary body behind and the cornea and corneo-scleral limbus in front. In the Sparrow the anterior pectinate fibres stretch from a line slightly posterior to the sclero-corneal junction about the termination of Descemet's membrane to the root of the iris. In some cases they may be traced more towards the middle zone of the iris.

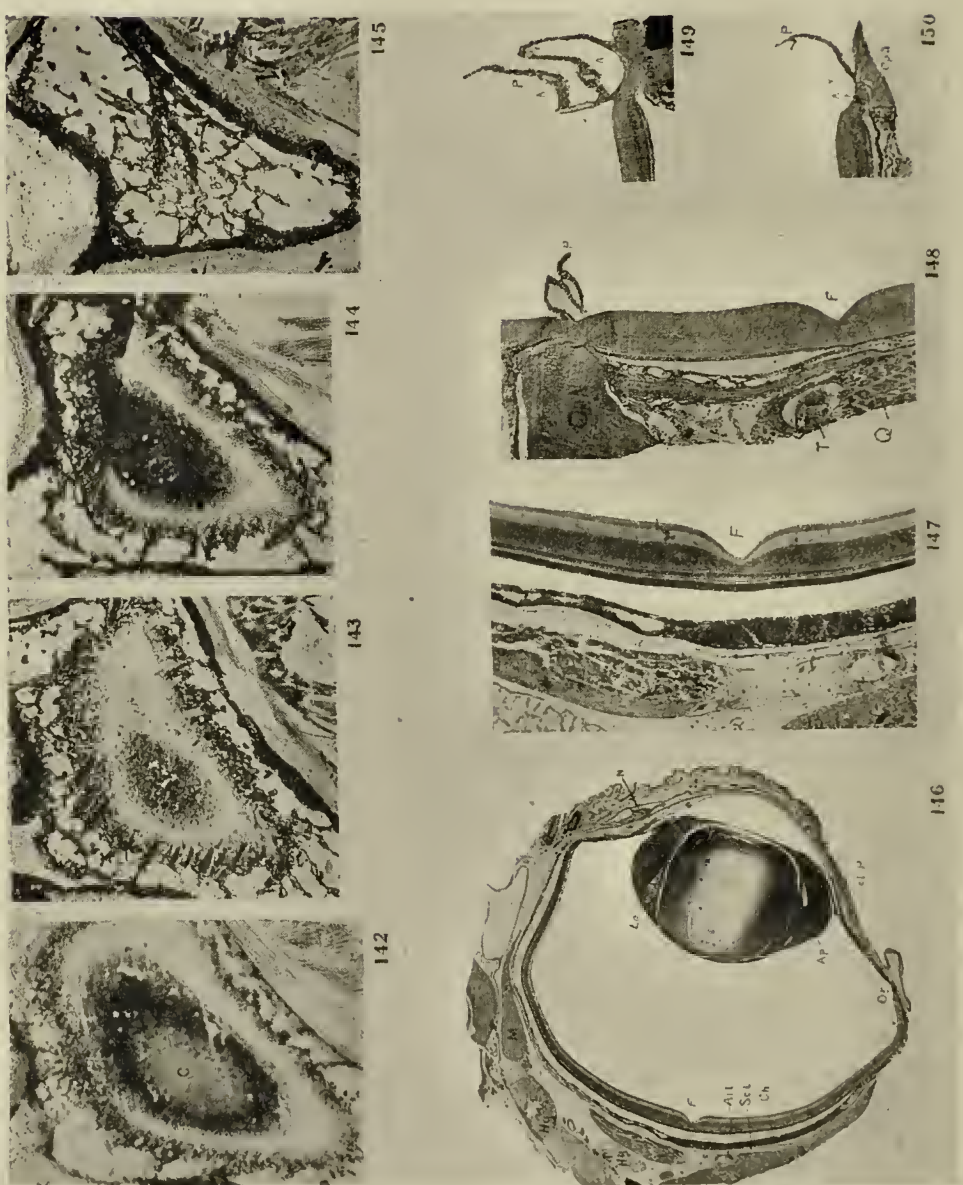
The fibres of the ligament have a frayed-out appearance in ordinary sections, probably because in death the pupil dilates widely and the ordinary tense fibres slacken and become doubled. The numerous, stout fibres that even in a delicate bird, like the Sparrow, crowd the sclero-iridian angle may, without any stretch of the imagination, act as "check ligaments" in holding taut the iris and ciliary body, when the pupil is fully contracted; relaxing, of course, in mydriasis. Both of these conditions are described and pictured in E. Wychgram's Ueber das Ligamentum pectinatum in Vogelauge (*Archiv. f. vergl. Ophthalm.* III, June, 1912). In the same figures the faint, almost invisible fibres of the zonula of Zinn are shown, leaving it an open question as to what part, if any, these shadowy fibrillæ take in the active accommodation of the bird.

Treacher Collins (Erasmus Wilson Lectures, *The Lancet,* Feb. 17 and 24, 1900) found the ligamentum pectinatum to be an extensive structure in birds. In the Pigeon he describes it as a number of delicate, radiating fibres and branching cells. He says "starting at the sclero-corneal margin a little anterior to the root of the iris it extends backwards a considerable distance between the striated muscle of Crampton and the portion of the ciliary body connected with the ciliary processes." He adds that the canal of Schlemm is large and in the sections remains wide open.



Ciliary Region of the Pigeon. x 38. (Zietzschmann.)
a, Sclerocorneal junction; *b,* inner layer (spur) of the cornea; *c,* lamella of the bony plates; *d,* corneal margin of the cartilage layer of the sclerotic; *e,* orbiculus ciliaris; *f,* ciliary processes in close proximity to the lens; *g,* sphincter pupillæ; *h,* Müller's portion of the sphincter, near the elastic fibres of Fontana's space at the periphery of the iris; *i,* corneal ring; *k,* space at the iridian angle; *l,* canal of Schlemm; *m,* conjunctiva; *n,* zonula ciliaris; *o,* lens and "Ringwulst"; *p, q, r,* ciliary muscle, comprising *p,* Crampton's muscle, *q,* Müller's muscle and *r,* Brücke's muscle.

Whatever be the merits of the question raised by Wychgram as to the verity and function of the ligamentum pectinatum in large birds, Slonaker and the writer have been unable even to demonstrate it in the Sparrow, and the impression gained by many examinations rather favors the claim of Franz that its appearance is due to dislaceration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Microphotographs of the Various Structures in the Adult Eye. (Wood and Slonaker.)

A, Artery at the base of the pecten; *Ap*, annular pad of the lens; *art*, artifact due to hardening; *Bv*, blood-vessels of the choroid; *Ch*, choroid; *F*, fovea; *Hg*, Harder's gland; *Lc*, lenticular chamber; *M*, muscles; *N*, nictitating membrane; *Op N*, optic nerve; *Or*, ora serrata; *P*, pecten; *Q*, quadratus muscle; *Scl*, sclerotic; *Scl P*, scleral plates; *T*, cross section of the tendon of pyramidalis muscle, passing through the loop of the quadratus muscle.

Fig. 142.—Section tangential to the retina. The middle oval portion *C*, is the cross section of the rods and cones. This is surrounded by a black circle representing the pigment layer. x 38.

Fig. 143.—Same series as Fig. 142 through the bases of the pigment cells in the center surrounded by the choroid with well-marked blood-vessels. x 38.

Fig. 144.—Same series as Fig. 142. The dark central area is a cross section of the middle portion of the pigment cells.

Fig. 145.—Same series as Fig. 142 through the outer portion of the choroid, showing fragments of blood-vessels. x 38.

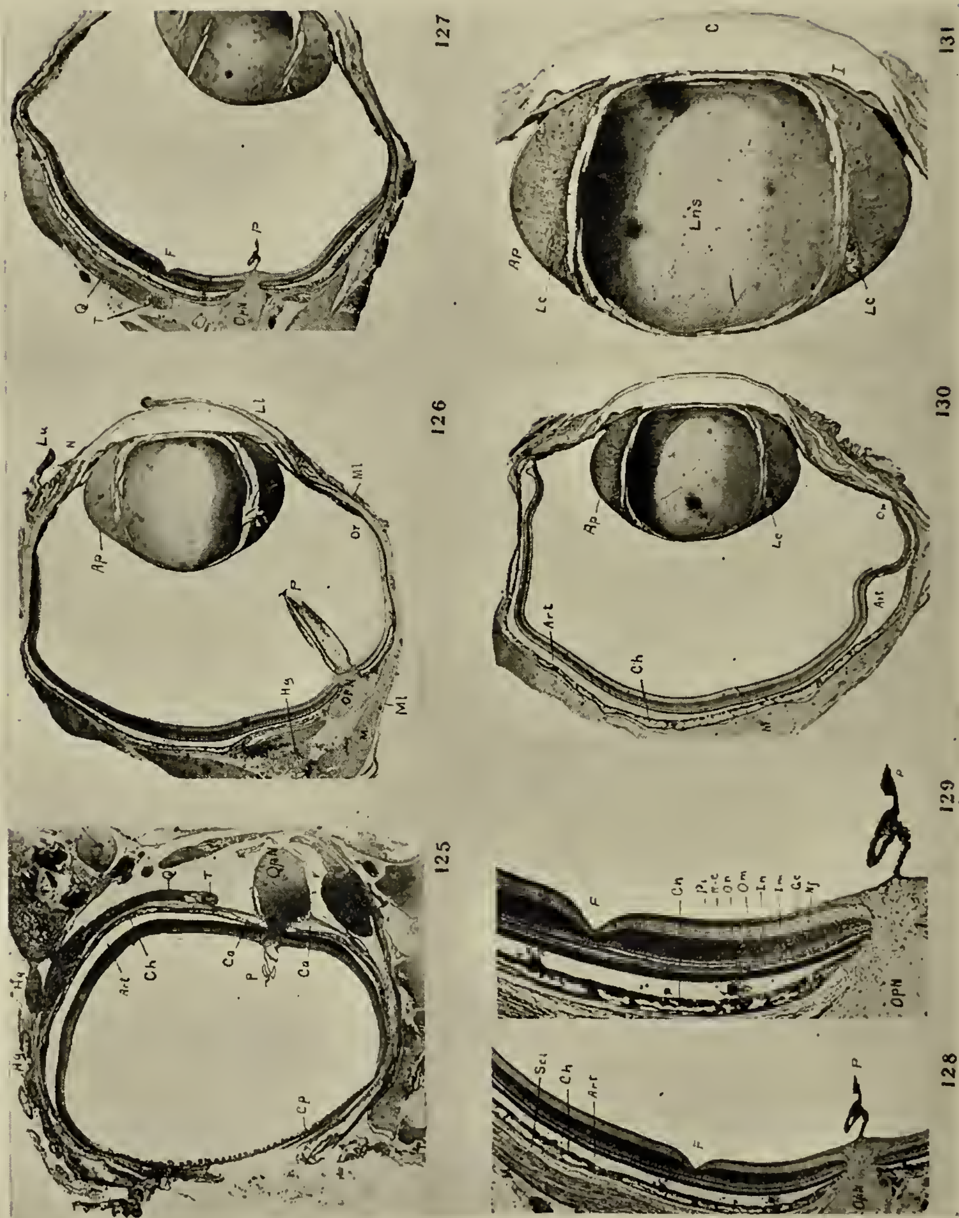
Fig. 146.—Horizontal section through the center of the pupil, lens and fovea of an adult eye. x 10.

Fig. 147.—The fovea of Fig. 146. x 40.

Fig. 148.—An oblique section of an adult eye passing through the optic nerve entrance and the fovea to show their relation. x 20.

Fig. 149.—Same series as Fig. 148, showing the arteries and veins of the folds of the pecten. x 15.

Fig. 150.—Same series as Fig. 148, showing the artery and vein at the base of the pecten. x 15.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Microphotographs Showing Various Structures of the Eye of the Sparrow. (Wood and Slonaker.)

Ap, Annular pad of the lens; *Art*, artifact due to hardening; *C*, cornea; *Ca*, thickened portion of the scleral cartilage surrounding the optic nerve entrance; *Ch*, choroid; *Cp*, ciliary processes; *F*, fovea, *Hg*, Harder's gland; *I*, iris; *Lc*, lenticular chamber; *Lns*, lens; *Ll*, lids; *Lu*, upper lid; *M*, eye muscles; *Ml*, muscles of the lower lid; *N*, nictitating membrane; *Op N*, optic nerve; *P*, pecten; *Q*, quadratus muscle; *Scl*, sclerotic; *T*, tendon of the pyramidalis muscle in the loop of quadratus. Retinal layers:—*Pi*, pigment; *R-C*, rods and cones; *On*, outer nuclear; *Om*, outer molecular; *In*, inner nuclear; *Im*, inner molecular; *Gc*, ganglion cells; *Nf*, nerve fibre layer.

Fig. 125.—Vertical section of the right eye of a young sparrow just able to fly. Section passes to one side of the lens but through the proximal entrance of the optic nerve. A portion of the outer layer of the sclerotic is diverted about the nerve to form its sheath. x 10.

Fig. 126.—Vertical section of an adult eye passing through the center of the lens. The thin movable lower lid is seen to extend well up over the front of the eye. x 10.

Fig. 127.—Same series as Fig. 126. Section passes through the center of the fovea. The fovea is typical for this bird. x 10.

Fig. 128.—Fovea of Fig. 127. x 18.

Fig. 129.—Fovea of Fig. 127. x 33.

Fig. 130.—Horizontal section of an adult eye showing the typical shape of the lens and relations of the different parts. x 10.

Fig. 131.—Lens of Fig. 130, more highly magnified to show the arrangement of the cells of the annular pad. The spaces are artifacts due to hardening. x 20.

only. It can readily be imagined how difficult it might be—even under favorable conditions of staining and sectioning—to recognize it among the delicate tissues of such a small bird as Passer.

In spite of the fact that Franz has attributed the appearance of a ligamentum pectinatum to dislaceration only, and that the difficulties of anatomical investigation are many, Wychgram, after studying the structures in the Kestrel, Pigeon and Crow—both in mydriasis and miosis—decided that the structure is a well-defined one, and its relative position during life may be demonstrated. He finds that it is divisible into three parts; first, a band passing to the anterior surface of the iris from an elevation to which also Crampton's muscle is generally attached. Second, fibres passing to the anterior part of the ciliary muscle. Third, loose fibrillæ that fill up the gaps between these and the outer angle. During an accommodative effort the fibres of the pectinate ligament are drawn quite taut. The writer thinks that accommodation in the bird mainly depends upon compression of the lens by the ciliary body and iris, and that the pectinate fibrils act as a sort of check ligament to prevent over-action. He believes this explains its marked development in the Cormorant, a diver needing (and possessing) a powerful accommodative apparatus.

Choroid of birds. The choroidea of Birds is always very thin, even in large eyes, but thicker than in the Mammal's eye. The capillary meshes of the choroid are of irregular size and rather narrow; in Struthio the capillaries are 0.01—0.02 mm. wide—broader than in other birds. The spaces between capillaries are, according to Franz, completely free of cells and pigment. The amount of pigment in the layer which extends outward is subject to variation.

Zietzschmann found the choroid of birds thicker than that of Mammals, but not so densely pigmented. The pigment cells, he says, are finer and more delicate and can easily be distinguished from those of the retina and pecten.

Slonaker found the choroid to be enlarged and most vascular (see figure) just opposite the fovea, through both embryonal and post-hatching life. It is one of the indications of the spot where the fovea will form, then it widens during the foveal formation, is seen at its widest about the time of hatching (when differentiation takes place most actively) and becomes thinner and remains permanent when the bird is several months old.

ACCOMMODATIVE APPARATUS AND REFRACTION OF VERTEBRATES.

A whole volume might easily be devoted to the refraction and accommodation of the eyes of the lower animals. In this *Encyclopedia* these subjects cannot, of course, be fully treated; and especially is it

impossible to discuss all the numerous disputed points connected with them; one may refer only to the more important.

Apart from Primates, Mammals have but a weak accommodative power. According to Kalt, neither eserin nor atropine has any effect upon the refraction of the Rabbit, the Horse, the Dog, or the Cat. Barrett developed in the Monkey 4 to 5 D. of myopia as the result of accommodation for near objects by exciting the eye electrically, and other observers have had similar results in other vertebrates.

Reptiles and Marine Turtles (examined under water) are emmetropic or slightly hypermetropic. Most Reptiles accommodate for short distances. As in Man, the curvature of the lens increases under accommodative action in Turtles, Lizards, and Crocodiles, while it is not affected in the accommodation of Snakes. The lens in Ophidia is pushed forward by the advancing vitreous body and it is at the same time compressed by a circular muscle situated at the root of the iris. The amplitude of accommodation is considerable in amphibian Reptiles.

Beer found among Amphibians a slight amount of accommodation, the Toads and Salamanders especially, while Frogs have none. Kalt (*Encyclopédie Française d'Ophtal.* III, p. 856) says that in Amphibians, *as in all the lower vertebrates, except Fishes,* the eye is adapted to infinity and is accommodated for near vision without changes in the curvature of the lens. The lens itself is pushed forward by the compression of the vitreous body. Meantime, the aqueous humor accumulates in the anterior chamber and presses the iris backwards. This statement, we believe, true of Birds and possibly of some Mammals is not applicable to Man, if the Helmholtz theory be accepted. It must also be remembered that Hess discovered (*Zoolog. Jahrb.*, Supplement, Vol. 3, p. 155) in Day Birds a direct opening between the anterior and posterior chambers, so that during the accommodative effort the aqueous may flow back and forth and so equalize the pressure in the two chambers.

The refraction of most Amphibians is emmetropic or slightly myopic. They have small or easily contracted pupils.

In fresh-water Fishes the cornea acts as a convex lens, while in marine varieties it has the effect of a slightly weak concave lens. Practically, however, this action of the cornea may be neglected while the animal is in the water, because the indices of the cornea and the aqueous humor are very close to that of water. When the fish has its head out of water the cornea, placed between the air and the aqueous humor, refracts the luminous rays more energetically, and, if, in the water the eye was emmetropic it becomes myopic as soon as it enters the

air. From this point of view, the passage from water to air is roughly equivalent to the addition to a plano-convex convergent lens, with an index equal to that of the humor (1.337) plus a radius equal to the radius of curvature of the cornea. In the case of a cornea having a radius of 10 mm. e. g., in *Labrax lupus,* this would give 33.7 D. For a cornea of 4 mm. radius, as in *Raja asterias* it is 84 D; for a cornea of 2 mm. radius, 168 D, as in *Solea vulgaris.*

In the same way one may make an approximate calculation of the hypermetropia acquired by the emmetropic eye of a terrestrial animal when it is plunged into water.

If a fish, emmetropic in the sea, passes into fresh water, it becomes myopic, since the fresh water has a lower index of refraction than the salt water and the aqueous humor; the passage from sea water into fresh water is nearly equivalent, from an optical point of view, to the addition of a plano-convex lens.

For the same reason a dissymmetry in the curvature of the different meridians of the cornea has less importance for sight under water than when the eye is in the air. Those animals, for example, which, in water, are not sensibly affected by their astigmatism, become so to a very noticeable degree when the cornea is in the air; as in the case of the Whale.

D. W. Stevenson (*Am. Jour. Ophthal.* 1891, p. 4) proposed that one neutralize the 35 to 40 dioptres of hyperopia produced in the human eye under water (by the elimination of the corneal refraction) by wearing glasses made in the shape of a hollow plano-concave lens of annealed glass.

"Being sealed with the air enclosed, its action under water would be the same as a strong convex lens in the air."

It could be made out of annealed glass of uniform thickness, the same as the flasks and retorts used in the laboratory. It might be rendered bi-convex in its interior, or bi-concave externally just as easy, requiring only one-half the curvature for each side, but I expect the refractive part of this glass ought to come as close to the eye as possible.

The curve on the glass or mould would not be near as great as the cornea because of the greater distance from the retina or nodal point.

Having found by experiments the proper curve of the mould, thousands of these spectacles could be blown out quite cheaply. When fitted in a nickel riding-frame, with an ordinary saddle (ss) nose piece, they could be made to fit any one, and perhaps would give some pleasure in diving. Many valuables remain lost in our lakes, especially

the tourists' lakes, like those of Wisconsin, because of the expense of sending for a diver who, with an elaborate apparatus, has air pumped to him to see and breathe by; also, because by the time he gets there, the valuables are covered.

A startling peculiarity of these glasses is that they have no effect on refraction in the air. Thus a swimmer could keep them on all the time, their action in the air being nothing more than that of a coquille (protective).

Matthiessen has also studied refraction of the eye of the Whale, *Balaenoptera sibbaldii.* This Mammal is 27 to 30 metres long and its eye, the largest of all animals, has also the largest intraocular capacity, 123 c.c., as well as the largest crystalline lens, whose capacity is 5 c.c. The eye resembles very much that of Fishes: the anterior capsule of the lens is very near (2 mm.) the cornea, the retinal surface is spherical, and nearly concentric with the nucleus of the crystalline, and the anterior half of the eye is strongly flattened. But the index of the lens is less than in Fishes (that organ being flattened more like that of terrestrial mammals) and its anterior surface is less convex than its posterior surface. The radius of curvature of the horizontal meridian of the anterior surface of the cornea at its summit is 62 mm., that of the vertical meridian, 37 mm. for the posterior surface the radii of curvature are respectively 24 mm. and 21 mm. The thickness of the cornea in its middle is 2 mm.

This asymmetry of the cornea exhibited by the Whale is of no importance when the animal is under water. In this situation it has a slight hypermetropia (0.44 D.) but this a weak accommodative effort may correct. But when the eye is out of water it is both astigmatic and myopic, the vertical meridian having a myopia of 7.55 D. and the horizontal meridian a myopia of 3.65 D., so that the eye has an astigmatism of 3.90 D. with the rule. The muscles of the eye being very powerful in the Whale, the lateral pressure exerted by them, may provide some accommodation. Perhaps there is also a displacement of the retina under the influence of variations in volume of the choroid, which in these animals is very thick.

The cornea of Fishes, having no refractive effect under water, the schematic eye of the Fish is reduced to the crystalline lens placed between two media of the same refractive index.

The point equally distant from the nodal points is always in the lens; very near its posterior pole in Man; almost at its center in Carnivora.

Refraction and accommodation of the eyes of Fishes. Beer proved

that the eyes of Fishes are decidedly myopic; Hirschberg, by means of the direct image of the ophthalmoscope, found the refraction of the Perch to be between 30 and 40 D. of myopia, and thought in the water the refraction of the piscian optical media would approach emmetropia; also, that the approach of the lens to the cornea would increase the refraction for near fixation.

A fish under the influence of curare and examined under water by skiascopy (the pupil in Fishes is almost immobile) showed from 3 to 12 dioptres of myopia; in the air the refractive defect varied from 40 to 90 D.

That the displacement of the piscian lens probably enables the fish to see better in the distance, whether some of the light rays do not pass through the lens at all or whether they are exposed to a part of the lenticular body whose refractive effect is much less than in the usual condition of near fixation, is not quite determined. Of the fact of the lenticular displacement, however, there seems no doubt.

In piscian eyes excited electrically, the lens may be plainly seen to be carried backwards and towards the temporal border of the eye. This *displacement of the lens* is well shown in many fishes. It is quite rapid in Pagellus, Labrus, and the Gobies; in others, Uranoscopus, for example, several seconds elapse between its beginning and its termination.

Cutting the campanula prevents any displacement of the lens.

Hess believes that the mechanism of accommodation in reptiles and birds differs completely from that of man. The pressure of the ciliary processes and iris on the extremely plastic lens of these animals causes a conical projection to bulge through the pupil, which adds, of course, to the refractive power of the dioptric media. During accommodation, therefore, the sauropsidan lens is under increased, the mammalian (if the v. Helmholtz theory be accepted) under diminished, pressure.

It is evident that animals which have to see under water as well as in the air must be provided with a powerful accommodation; for, as soon as they dive under the surface, the whole refractive power of the cornea is abolished, and the eye must become very hypermetropic. Fritzberg *(Archiv f. vergl. Ophthalm.,* June, 1913) maintains that if the above explanation of Hess be correct, the musculature of the ciliary body and iris must be developed, in the case of birds and reptiles, in proportion to the accommodative requirements, whereas this is not necessarily the case in mammals; because if complete relaxation of pressure on the lens capsule is obtainable by a certain muscular effort,

no object can be served by any further muscular development. In the case of birds and reptiles, the range of accommodation could be increased to almost any extent by increased muscular power; in man, on the other hand, an increase of muscular power would be useless without a change in the constitution of the lens, and, indeed, in the case of presbyopia the muscular power which he possesses becomes useless owing to loss of plasticity in the lens. If this reasoning be correct, the intra-ocular musculature of the powerfully accommodating amphibious Reptiles and Birds ought to be greatly in excess of that of the purely terrestrial members of these classes.

Hess has already shown that this holds good in the case of the Cormorant, which sees its prey from above and chases it under water. Fritzberg takes up the same question in the case of the land and water Tortoises. In all the water animals he finds the muscles of the iris and ciliary body much more highly developed than in their terrestrial relatives. The great development of the iris muscle is very characteristic of the water animals. It is obviously far in excess of what is required for the movements of the pupil; indeed, it can be shown experimentally that the pupil in these animals does not respond to light, but only to accommodation. Therefore the muscle fibres of the iris must form a part of the accommodative mechanism, and, in fact, they are well placed to exercise pressure on the lens in the manner described above.

Fritzberg describes also some details of the reptilian iris and ciliary body. He finds that in amphibious animals there is a much more richly developed plexus of vessels in the iris. This he believes to represent a mechanism for the regulation of the intra-ocular pressure. It is evident that if a portion of the lens is projected through the pupil, room must be made for the displaced aqueous. Fritzberg explains that the vascular plexuses are supplied from the ciliary body behind. When, therefore, the ciliary muscle goes into powerful contraction, the supplying vessels are more or less constricted, while at the same time the venous outflow by the vessels at the sclero-corneal junction is unobstructed.

The indices of refraction of the ocular media. Many methods have been proposed for measuring the indices of refraction of the media of the eye. Abbe's experiments have shown that the *indices of the different media are practically the same in all species.* The index of the cornea is about 1.377; the aqueous humor, 1.337; the vitreous, 1.335; the lens capsule, 1.365, and that of the inner layers of the crystalline, 1.385.

Ocular dioptrics among Vertebrates. A study of the refraction and accommodation of the eyes of Vertebrates has been carried out by several observers, Matthiessen and Lindsay Johnson especially. Of course, owing to the enormous number of species and for other obvious reasons, refraction statistics touching the lower animals are not so accurate or comprehensive as those reported in the case of Man.

The refraction of the cornea. It is by means of the combined action of the cornea and the crystalline lens that rays of light penetrate the eye and converge upon the retina, but the optical rôle of the cornea and of the lens does not have the same relative importance in all Vertebrates. In the human animal, in Monkeys and in Birds, the *refractive action of the cornea* is predominant; but this is not the case in other Mammals, nor in Fishes. The following table gives the respective focal distances of the cornea and the crystalline lens in representative Vertebrates, and their relations:—

Table (Kalt and Dufour).

	Focal Distance of the Cornea mm.	Focal Distance of the Crystalline Lens mm.	Relation 1 to
Man	31.2	49.2	1.60
Crow	25.8	36.7	1.42
Horse	78.8	64.4	0.82
Dog	33.8	22.9	0.60
Whale (out of water)	314.3	40.5	0.13
Carp	38.0	6.6	0.17

The accommodation apparatus of Birds.—In Birds the anterior segment of the eyeball is formed by the cornea and the fore-part of the sclerotic. The anterior chamber, usually very deep, is bounded by the diaphragm of the iris. The striated ciliary muscle, composed of fibres running in an antero-posterior direction, is applied directly to the ocular wall. It is separated from the ciliary body proper by a space of Fontana which communicates in front with the anterior chamber, and is traversed in front by the filaments of the pectinate ligament which unites the base of the iris and the external surface of the ciliary body.

In large birds, such as the Turkey-cock, or a bird of prey (the Horned-owl or the Falcon, for example) the internal musculature is more developed than in the domestic birds, such as the Hen or Pigeon. The cornea is thin; its margins are covered to a slight extent by the

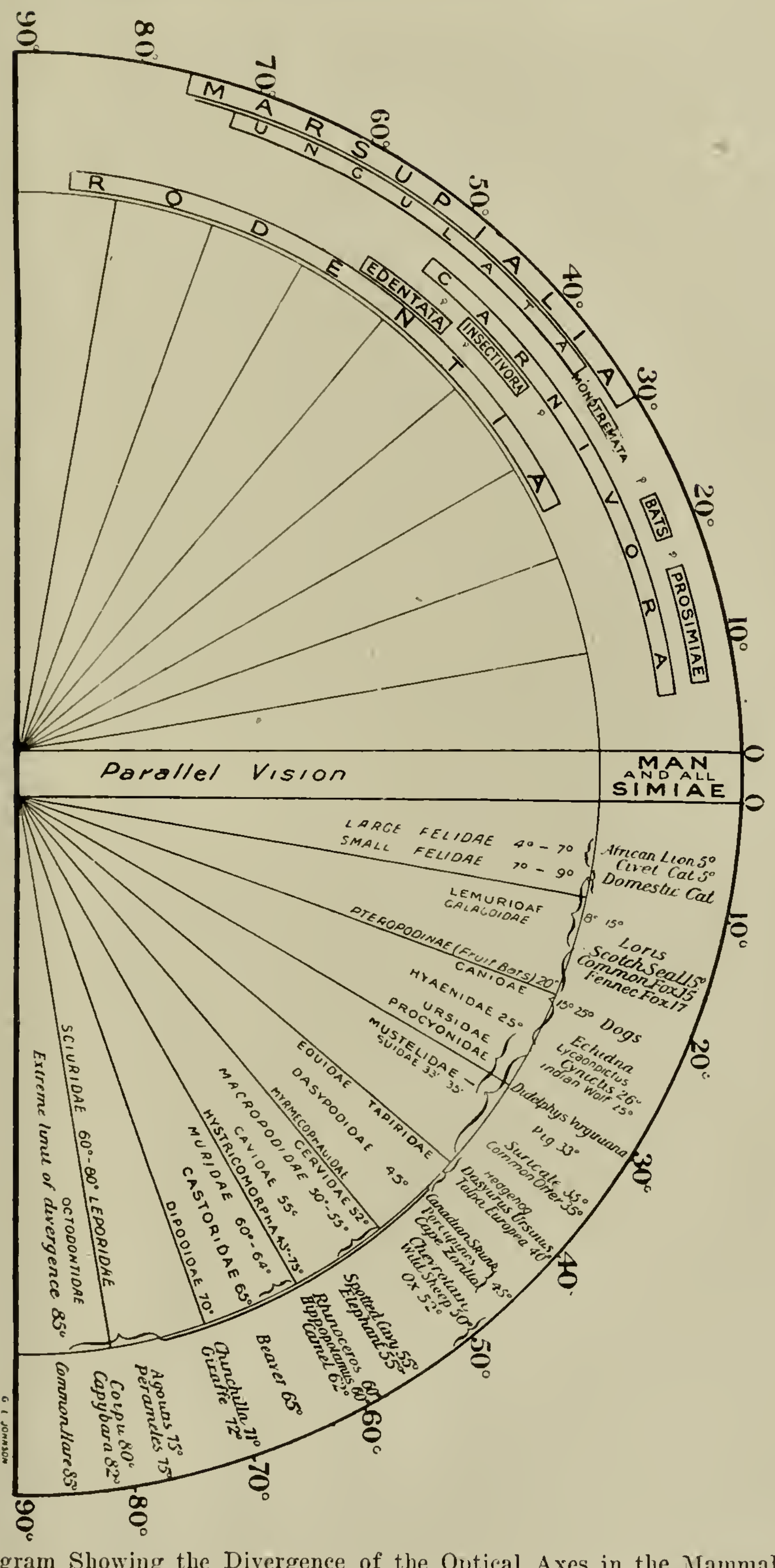


Diagram Showing the Divergence of the Optical Axes in the Mammalia. The Natural Orders Are Represented on the Left-hand Quadrant, the Families, Genera and Species on the Right. (After Lindsay Johnson.)

sclerotic, with which it blends. In its centre, the lamellæ of which it is composed are so interwoven that they are inseparable, but towards the periphery they appear to spread into two layers of which the posterior, which is also the thinner, seems to be only loosely united to the upper layer. The deeper layer does not continue into the sclerotic; it separates from the upper layer and ends at a sharp edge which faces the root of the iris. This *circular ridge* furnishes an entrance at its anterior surface to the fibres of the pectinate ligament, which is directed, in the form of a fan, towards the root of the iris and the external face of the ciliary body. The muscle fibres which constitute the two principal bundles of the accommodative muscle (muscles of Crampton and Müller) are attached to this ridge.

This muscle, discovered by Crampton in 1824, is really composed of three parts: the muscle of Crampton, the muscle of Müller and the bundle of Bruecke, of which the last-named has also been styled the *tensor of the choroid.*

The *muscle of Crampton* occupies the angle included between the circular ridge of the cornea just described and the sclerotic, while the muscle of Müller is inserted into the free edge of the circular ridge. Thence its fibres are carried posteriorly to be inserted in the external surface of the choroid. Finally, the bundle of Bruecke is attached to the sclera, and after passing some distance to the rear loses itself in the choroid.

From a study of these anatomical relations one may conclude that contraction of the muscle of Crampton would have the effect of drawing the deeper layer of the cornea downwards and backwards.

The muscle of Müller has a similar action. In addition, it draws the choroid forward, and this last action is, without doubt, the sole function of the bundle of Bruecke. It is to be noted, meanwhile, that the antero-posterior direction of all the muscle fibres, which has been universally admitted until quite recently, has not been actually demonstrated. Heine (Graefe's *Archiv f. Ophthal.,* 45, 1898) in fixing the muscles by means of myotics, was sure that the mass of muscle tissue separated and projected into the interior of the eye-ball.

The iris of the Bird, which is very mobile, is provided with a muscular layer which is visible to the naked eye in certain species. One can readily distinguish microscopically the radiating fibres for pupil dilation, and the circular fibres which constitute the sphincter of the pupil. The latter extend in a continuous layer over the anterior surface of the iris, from its ciliary edge to the pupil. The thickness of the layer is greater at the periphery than at the center, except.

however, at the level of the ciliary insertion where the fibres are often lacking, as in Night Birds.

Behind the layer of circular fibres is found a thinner layer of radiating fibres. These two layers exchange numerous anastomoses in the form of arches; entire bundles of fibres even pass from one layer to the other. At the periphery of the iris the dilating fibres cross over into the ciliary body.

The *ciliary body* is reduced here to the corona ciliaris whose lower surface is covered by numerous folds which have an antero-posterior direction. These ciliary processes, to the number of several hundreds, present an unequal development. Between two well-developed processes, whose anterior ends mold themselves upon the equatorial portion of the crystalline lens, one may count four or five which do not reach or touch the lens. In Birds of Prey the head of the ciliary processes is covered with small vascular excrescences and intimate connections exist with the neighboring surface of the lens capsule. The equator of the crystalline is therefore enclosed in a narrow circular groove which the ciliary processes form about it.

It is understood that, in these circumstances, the canal of Petit and the zonule are lacking. The zonulary fibres exist, however, and bind the ciliary processes to the body of the lens below.

There is one problem, viz., accommodation mechanism, to which no satisfactory explanation has been given up to the present moment.

Among the authors who are engaged in explaining this complicated mechanism, should be mentioned Bruecke (1846), Cramer (1853), H. Müller, Beer, and more recently, von Plugk, Hess, Franz, Zietzschmann and others.

The ciliary muscle evidently constitutes the principal organ of accommodation. It is no longer possible to attach much importance to the action of the pecten: the hypothesis of its taking part in the accommodative act was definitely abandoned after the researches of Tiedemann, Treviranus, Leuckart, and Zierm.

The function of the muscle of Crampton is the most difficult of explanation. Crampton thought that its contraction had the effect of increasing the radius of curvature of the cornea; Bruecke attributed to it the opposite effect, while Cramer denied it any action in that sense. H. Müller admitted that the contraction of the muscle fibres of the iris exercised traction upon the ciliary body and, indirectly, upon the equator of the lens, thus causing a convexity of the anterior surface of the crystalline. At the same time, the lens body is held in place by the vitreous upon which rests the choroid, drawn forward by the muscle of Bruecke.

Trautvetter recognized (Graefe's *Archiv f. Ophthal,* XII, 1866) the fact that exciting the ocular-motor nerve had the effect of diminishing the size of the image furnished by the anterior segment of the lens. He noted that preliminary section of the iris did not affect the result.

Leuckart agreed with Cramer that the increase in curvature of the lens is due to the contraction of the fibres in the periphery of the iris, while Exner thought that, in contracting, the ciliary muscle draws forward the choroid and at the same time weakens the traction which the pectinate ligament exercises upon the lens with the help of the ciliary body and the zonula. The lens, left to itself, would then tend to take a more spherical form. This explanation is practically the same as that given by Helmholtz in Mammalia.

Beer (*Archiv f. d. ges. Physiologie,* 53, 1893) has taken up the question in a large number of birds. He proved that the electrical excitation of the muscle of Crampton does not modify the size of the images of the cornea in the Hen or the Pigeon; but in a series of the Owl family it produced a flattening of the periphery of the cornea. At the same time the curvature of the central circle of the cornea, about the visual axis, diminished slightly. After resection of the central corneal area, it was found that the peripheral zone was drawn inward under the influence of the contraction of the muscle. There is then, among the birds of prey a degree of accommodation due to change in the shape of the cornea.

Shortening of the radius of curvature of the anterior surface of the crystalline lens is, however, the principal factor in accommodation.

According to Kalt the lens is maintained normally in a contracted or flattened condition by the elastic traction of the strong pectinate ligament. The contraction of the muscle of Crampton and perhaps also of Müller's muscle draws and displaces, inside, the lower layers of the cornea; consequently the pectinate ligament is released and the crystalline lens, pulled by its own elasticity, takes a more spherical shape. The same result is obtained by cutting the pectinate ligament; the excitation of the accommodating muscle is then without effect upon the lens.

Heine confirms the preceding statements. For him, however, the releasing of the pectinate ligament has not been demonstrated. The contraction of the ciliary muscle, composed of antero-posterior and oblique fibres, draws together the ring of the choroid (to which the zonular fibres are attached) and, consequently, releases the zonule. This author has found in the Pigeon, under the influence of miotics

and faradic excitation, an increase of the refraction up to 12 diopters, the eye being originally hypermetropic—1 to 2 diopters. Localized excitation of the muscle even produced an astigmatism of several diopters.

Th. Beer (*Archiv f. Anat. u. Physiol.* (*Pflügers*), Vol. 53, p. 235), believes that Crampton's muscle exerts by its contraction a pull upon the internal cornea lamellæ which, in turn, are pushed against the periphery. This action can be traced as far as the neighborhood of the center of the cornea. In the Owls and other nocturnal birds of

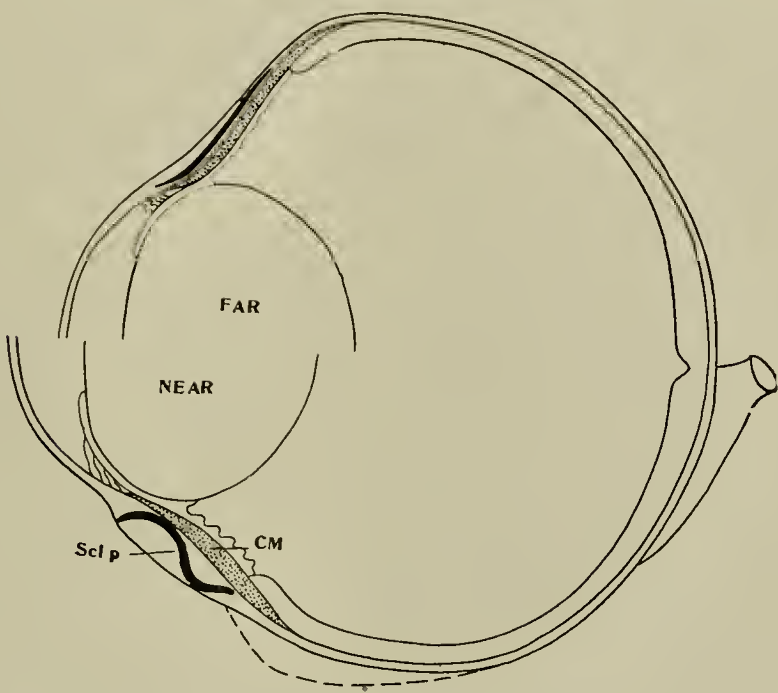


Diagram of Changes in Shape and Position of the Cornea, Lens and Pupil during Accommodation of the Sparrow's Eye, for Far and Near Objects. (Wood and Slonaker.)
CM, ciliary muscles; Scl p, scleral plates.

prey the cornea becomes flattened through the contraction of Crampton's muscle in the peripheral parts, and the radius of curvature becomes greater, in the center of the cornea. There is thus provided an accommodation for near objects.

The main function of accommodation is, however, a change in the curvature of the anterior lens-surface; the latter moves forward somewhat and becomes simultaneously more convex.

After much consideration of the subject and many experiments on both dead and living material Slonaker and the writer conclude that *accommodation in the Sparrow's eye* is brought about as follows: The compound muscle or muscles of Müller, Crampton and Brücke,

constituting the striped ciliary muscle, are attached along and form the internal layer of the sclera, from the region of the sclero-corneal junction (which may be regarded as its anterior point of origin) to a point in the choroid well past the pars ciliaris behind the true retina.

In a state of rest the ocular organs involved in accommodation are adjusted for distant vision. The ever-varying pupil is then about 2 mm. wide, the pectinate ligament is in folds, and the cornea is rounded. When the bird accommodates the ciliary muscle contracts and the parts along its whole extent are involved in a sort of foreshortening. The entire globe then becomes more cylindrical, the bony plates are more curved and tense, the angle formed by the junction of the posterior cup of the eyeball with the spheric segment of the cornea becomes greater and the pupil is smaller, owing to contraction of the circular muscle of the iris.

The latitudinal shortening of the eye-coats behind the zone covered by the ciliary muscle also brings about an increase of intraocular pressure. Inasmuch as the bird's cornea forms the only *elastic* segment of the eyeball—the remainder being really an inelastic cartilaginous cup—it yields to the increased ocular pressure of the ciliary muscle, bulges forward and becomes more convex. As a consequence of this yielding of the cornea to the pressure behind it, the whole lens system must necessarily come forward.

The ciliary processes being firmly attached to the globe in the region of the contraction of the eye-coats also exert some pressure from behind upon the equator of the Ringwulst, also pushing it and the true lens forward and (perhaps) making the latter slightly more convex in front, although this latter change does not form an essential part of the accommodative act. Partly as a result of the contraction of the iridic fibres in the miosis of accommodation for near, and partly because of the forward thrust of the ciliary processes the pectinate ligament is elongated and made more tense; it seems to act in this connection as the check ligament of the iris and ciliary processes. Finally, it is in all probability through increase in corneal curvature that increase in the refraction of the bird's eye mainly occurs, although it may readily be seen that such a powerful refracting agent as the avian lens must produce a decided effect as it approaches or recedes from the retinal sheet.

Very likely the anterior chamber does not (as a part of the accommodative change) vary much in relative depth, the advance of the corneal centre and anterior lens pole being about the same; nevertheless, if the opening which Hess (*Zoologisches Jahrbuch,* Supple-

ment 15, Vol. 3, 1912) found in the ciliary ring of Day Birds does regulate the intraocular pressure, is present in the Sparrow (not yet discovered by Slonaker and the writer) there may be a continual variation in the depth of that bird's anterior chamber.

The resiliency of the osseous plates, the cartilage cup and the cornea, but especially the first named, is the chief causes of a return to the *statu quo ante* when the accommodative effort has passed.

Slonaker (p. c.) has recently made the following experiment: "Before killing the sparrows I performed a physiological experiment to test the theory of accommodation; and think it most conclusive. After the bird was under the influence of a general anesthetic I removed the lids so as to expose the eyeball at the ciliary region. Using platinum electrodes and a faradizing current, I stimulated the outside of the ball. Owing to the ciliary plexus the stimulus was distributed to all the ciliary muscles. With each stimulus (which caused a shortening of the ciliary muscles) the lens, iris and cornea moved very noticeably forward. The lens seemed to have a greater amplitude than the cornea. I had a student tell me what he saw and he independently confirmed my observation. I feel confident that I have definitely proved on the live bird the theory of accommodation previously advanced."

THE RETINA OF VERTEBRATES.

The structure of the retina, as Greeff (*Guide to the Microscopic Examination of the Eye*, p. 78) and others have pointed out, is surprisingly uniform in all vertebrates, including Man. (See **Anatomy of the eye,** as well as **Histology of the eye** in this *Encyclopedia.*) The layers are always the same unless in Petromyzon and in a few members with rudimentary eyes. The main differences are found in the form and number of the rods and cones, due to the peculiarity of each animal's vision.

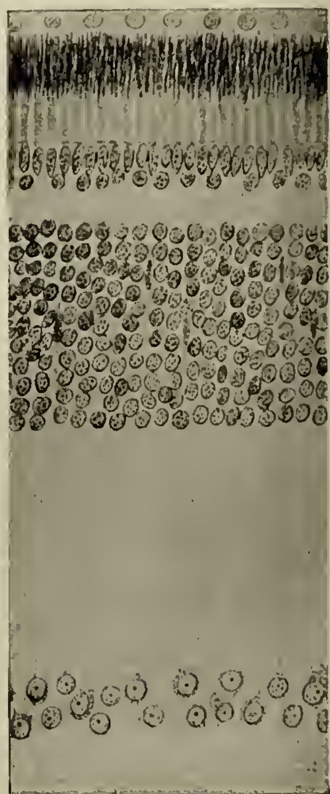
The retina of Mammals closely resembles that of Fishes, the only difference being that in the latter there are fewer elements, and, as a consequence, a simpler structure.

In Birds and Amphibians the retina is distinguished by having the outer nuclear layer thinner than the inner. The opposite is usually the case.

Comparative views of the various layers of this important ocular coat are seen in the accompanying illustration, taken from Pütter (Graefe-Saemisch-Hess *Handbuch der ges. Augenheilk*, 3rd edition, 1913), who adapted from P. Chiarini's work.

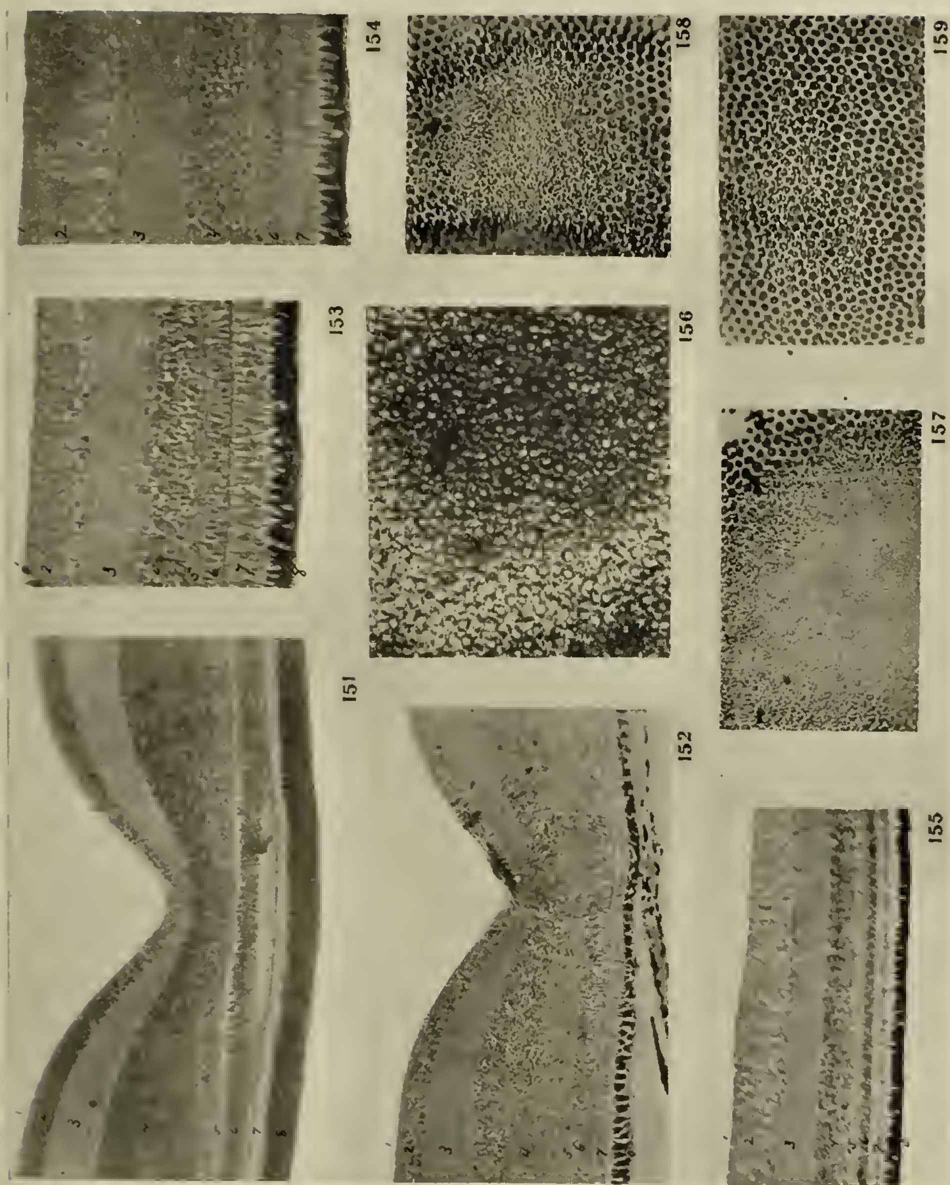
Retinal circulation in Mammals. Lindsay Johnson *(loco cit.)* divides the retinal blood-supply as follows: *(a)* circulation well developed,

with central artery and vein and their branches supplied to the entire retina. This form he calls *euangiotic.* *(b)* Partially developed circulation, many of the nutrient vessels appearing at the circumference of the retina—*angiotic.* *(c)* The retinal vessels are almost wanting, or are very short or with difficulty visible with the ophthalmoscope—*pseudoangiotic.* *(d)* No vessels are seen with the ophthalmoscope—*an-angiotic.*



Pigment movement in the retina of the Lizard under the influence of light. (After P. Chiarini.)

Leber (*Handbuch der ges. Augenheilk.,* 2nd Ed., Vol. 2, 1903) prefers the following classification: (1) retinas with complete vascularization—*holangic.* These may be divided into *(a)* vessels that emerge from the centre of the papilla, as in Primates, some Insectivoræ and Carnivoræ, and *(b)* as in the Pinnipedia, Felidæ and Rodents, where some of the vessels emerge at the border of the disc and may be of ciliary origin. (2) Retinas with a partial but evident vascularization—*merangic.* This type is found in certain of the Rodents, the Rabbit, for example. (3) Retinas with a circulation developed only at the optic papilla and the circumpapillary region—*paurangic.* (4) Retinæ entirely devoid of vessels visible with the ophthalmoscope—*anangic.* This condition is seen in most of the Marsupials, except Didelphus and Dasyurus, in the Elephant, Horse, Beaver, and Tapir.



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The Retina of the Sparrow.

1, Nerve fibre layer; 2, nerve cell layer; 3, inner molecular layer; 4, inner nuclear layer; 5, outer molecular layer; 6, outer nuclear layer; 7, rod and cone layer; 8, pigment layer. (Wood and Slonaker.)

Fig. 151.—Horizontal section through the center of the fovea of the adult, showing relative thickness and arrangement of the layers. The cones show the marked lengthening and slanting arrangement found at the center of the fovea. x 170.

Fig. 152.—Section through the adult eye slightly to one side of the center of the fovea. x 170.

Fig. 153.—Section through the retina of an adult a short distance from the fovea. x 250.

Fig. 154 and 155.—Section through the retina of an adult farther from the fovea than Fig. 153, Fig. 154, x 500; Fig. 155, x 250.

Fig. 156.—Section tangential to the retina of an adult through the inner portion of the pigment layer, showing cut ends of the rods and cones. x 250.

Fig. 157.—Section tangential to the retina of an adult through the inner segments of the rods and cones. x 170.

Fig. 158.—Section tangential to the retina of an adult through the outer segments of the rods and cones. x 170.

Fig. 159.—Section tangential to the retina of an adult through the pigment cells. x 170.

In the Echidna, Hystrix and Rhinoceros the fundus shows no vessels with the ophthalmoscope.

The central area of the retina. The area represents a thick portion of the retina when the arrangement of the elements recalls that observed at the level of the "yellow spot" of the human retina. There is an increase of ganglionic cells and of the receiving elements —the cones and rods.

The form of the central area is variable; sometimes it gives the effect of a distinct transverse line, dividing the retina into unequal parts, as in the Crocodile; frequently it shows as one or more rounded spots.

The *fovea,* which characterizes the area of Man and Monkeys, may exist simultaneously with the area.

The *area centralis retinæ* is found in all classes of vertebrates and its presence is the rule. It is found constantly in Reptiles and Birds. On the contrary, it is lacking in certain mammalian groups, and in some amphibia.

The area is far from being always situated in the center of the retina. It is external to the papilla in Man, underneath it in the Tortoise, above it in the Fox.

A strip-like area stretches transversely below the papilla of the Horse; above it in the Hare.

Gustav Fritsch (*Archiv. f. mikroskop. Anatomie,* Vol. 78, p. 245, 1911) believes that true rods and cones are found in Birds, just as they are in Mammals, and they should be designated as such. In the region of the *fovea centralis* there is also a dwarfed, cone-like form. The colored droplets of Bird's appear mostly in the rod elements, although they are sometimes seen in conjunction with cones. Among the central cones is also found, quite commonly, a body which is colored brown by osmic acid.

The acuteness of the Bird's vision is probably due to the fineness and close arrangement of the retinal elements.

The retina of Birds. The following account closely follows the classic description given by Franz (*Das Vogelauge,* 1911).

In these animals the layers of the retina are more sharply defined than in any of the other vertebrates; even more than in Mammals. There are no separate bipolar or optical ganglion cells in birds, while we find in mammals isolated amacrine cells, and, in reptiles, bipolar cells, etc.

All birds possess rods as well as cones, although in very different arrangements. H. Müller erroneously depicted the cones of the Pigeon

with long cylindrical extremities, when these really belong to the rods. The cones have each a single oil droplet, whose color varies. Cajal has differentiated (in birds) as in reptiles "straight" and "oblique" cones.

The nuclei of the cones usually lie inside the *membrana limitans externa.* Several "oblique" cones have an enlargement of the end inside the inner layer of nuclei. The "twin" cones, whose nuclei are not to be seen, lie near the *membrana limitans;* the smaller nucleus of the pair is in a facet of the larger. The rod nuclei are usually found in the internal half of the nuclear layer. Their small end branches in the outer reticular layer, stretching out farther than the end of the cone. The rod in nocturnal birds ends in the external portion of the outer reticular layer with a nodosity, a little ball at the end without any branches.

Separate bipolars do not exist in the external nuclear layer.

The external layer. Cajal differentiates three superimposed plexuses: the first, composed of the basal fibrils of the rods; the second, the end-threads of the straight cones; the third, fibrils which emanate from the oblique cones, that in every cell come in contact with the dendrites of certain bipolars and longitudinal ganglion cells.

Just as in Reptiles, Schiefferdecker found in the Chicken, Crow and Goose, in the external reticular nuclear layer, concentric supporting cells without nuclei.

The inner nuclear layer. One finds on the extreme outer aspect horizontal ganglion cells and *(a)* brush-like cells of Cajal, with many projections and a long horizontal cylinder which, like the short projections, bends around the outer reticularis and ends there with an enlargement and branches; *(b)* star-like cells with somewhat longer dendrites and a short cylinder which first turns in and then out. Between, and further in than the cells which Schiefferdecker calls nucleated cells, are found two kinds of bipolars: first, outer bipolars with highly developed dendrites, and internal, small or thin bipolars with weaker dendrites. The thick bipolars seem to branch out in the fifth layer of the internal reticularis; the thin bipolars assume more the form of a layer in the inner reticularis.

As in all animals, the nuclei of the supporting fibres of Müller are situated in the internal nuclear layer.

In the inner portion of the internal nuclear layer are found, as ganglion cells, the layer of amacrine cells, which are divided, as in Reptiles, in (1) nervous and (2) proper amacrine cells.

The layer of ganglion cells. Cajal differentiates the following types of ganglion optical cells: *(a)* single-layered cells, spreading out over

the internal reticular layer, partly multi-polar, but mostly belonging to the reticularis; *(b)* many-layered, multi-polar cells. The smallest are plentiful in the Passeres, i. e., the Sparrow, Chaffinch, Greenfinch, and different sub-types are to be distinguished. Diffuse ganglion cells, on the other hand, have not been described in the Bird.

It should be noticed that Dogiel expressed the opinion that those cells which in form, size, and character of branching of the protoplasmal and cylindrical processes, etc., belong to a certain characteristic type, anastomose with each other, or form a "colony."

The relatively thick, optic connective tissue next receives single, dissimilar, thick filaments, which, originating centrifugally from the optic nerve, intermingle with the internal plexiform tissue and end, according to Cajal, on the level of the amacrine cell-layer. Dogiel (1905) divides the centrifugal filaments into dividing and non-dividing fibrils.

Differences in retinal elements. As in almost all of the sub-classes of vertebrates, so are differences in the retinæ of Birds, especially in the tissues of the rods and cones.

The numerical proportion of rods to cones in different species is quite marked. Richest in cones are the diurnal Birds of Prey. These are referred to in Night Owls as "rod-retinæ." M. Schultze thinks that while Owls have many long rods, they have few cones; Krause thinks that the cones were invisible on account of the number and length of the rods, and that they were no less numerous in the Owl than in the Falcon.

Geese have, according to Krause, many long rods and stand in that respect midway between Owls and diurnal Birds of Prey. The Flamingo has the longest of all rod extremities. The Heron has many thick rods. In Nyctaetus, the rods are as long as in the Owls, but at least twice as thick; the cones are scarce.

Krause seeks to weaken the force of the statement of Schultze, that nocturnal Birds are distinguished by the preponderance of cones and a diminished number of rods, by pointing to the discovery of Heinemann that in the nocturnal Nycticorax (the Night Heron) the rods are scarce; that the Swallows, Hirundo rustica and Chelidon urbica, by the relative increase of their cones resemble the Owls, while Athena noctua possesses even more cones than rods. According to Hess, the number of cones in the Owl's retina reaches 1 to 2½ millions.

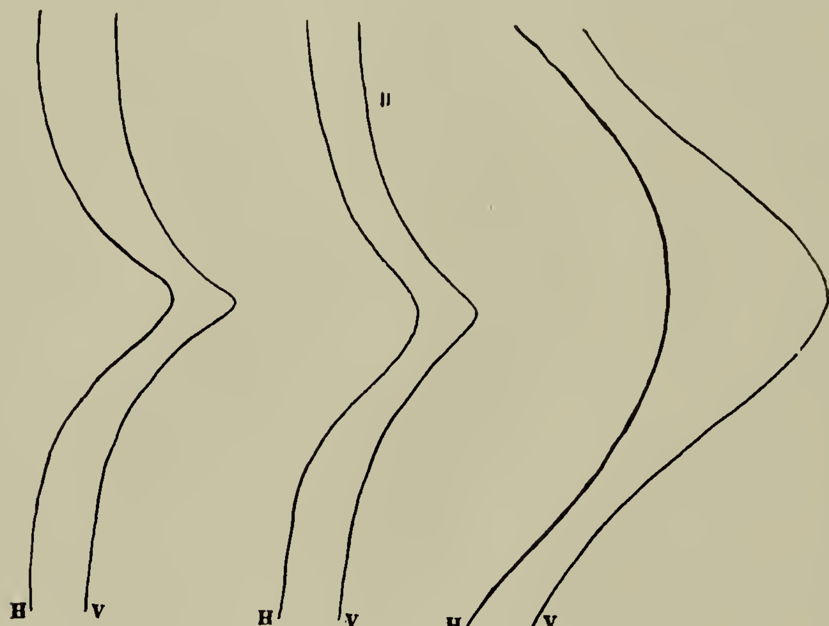
However the teaching of Schultze has much in its favor, in so far as that the hypothesis supported by it, that the cones are really color percipient organs, the rods of light and darkness and that rods alone are found only in deep-sea fish and Whales.

The Cormorant is said by Heinemann to have only cones.

In any event, as a rule, Day Birds are relatively richer in cones than Night Birds.

Picus canus (the Grey Woodpecker) is said to have many double cones, among them an occasional twin-cone.

Regarding the possession of oil droplets, ellipsoids, paraboloids and hyperboloids, there are, according to Krause, many differences in species. In Cardinalis virginanus and Fringilla spinus, Krause dif-



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Camera Lucida Tracings of the Outline of the Adult Fovea of the English Sparrow. (Wood and Slonaker.)

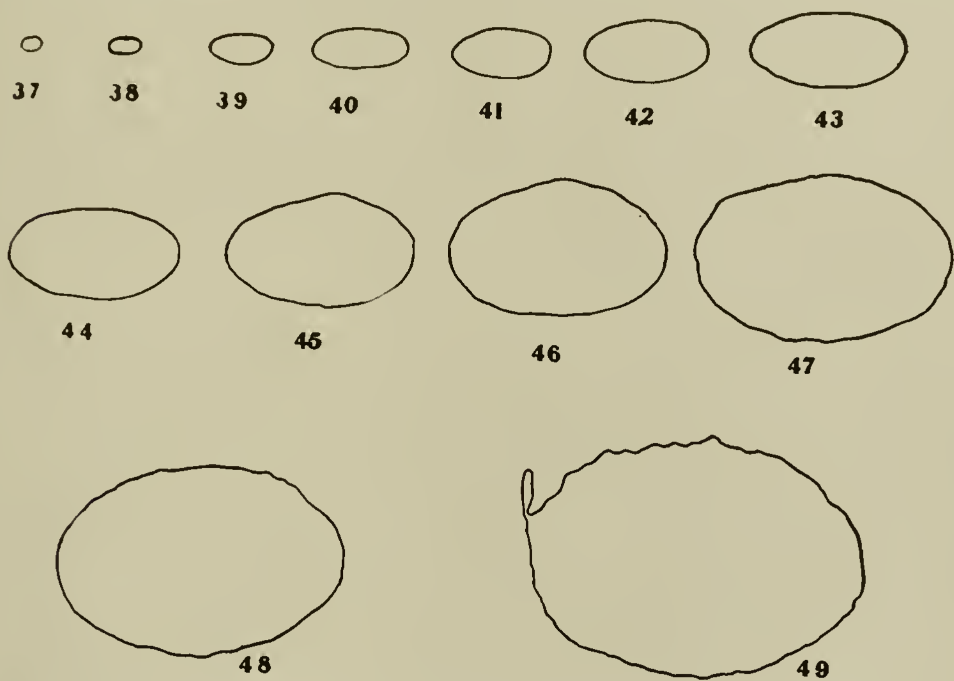
Fig. 34.—H, horizontal; V, vertical of the same specimen. x 125.
Fig. 35.—H, horizontal; V, vertical of a different specimen. x 125.
Fig. 36.—H, horizontal; V, vertical of the same specimen as Fig. 35. x 450.

ferentiated two kinds of cones; in the Hen three outer double cones. Fringilla spinus shows a blue oil droplet in many of its double cones.

As far as the color of the oil droplet in general is concerned, Schultze differentiates mainly (a) colorless, (b) yellow to reddish-yellow and red, and he again finds a difference between Day Birds and Owls in that the red are lacking in the latter while in them the pale yellow and colorless varieties are more plentiful.

The layer of nerve filaments receives in the Pigeon and a few other birds partly medullated fibres. Franz finds in many birds that the layer of nerve filaments in the vicinity of the optic foramen is still thick, which in mammals we call spider cells (Spinnenzellen).

Pigment movement in the retina of Birds. Although this strange phenomenon probably occurs in most vertebrates, and to a slight extent in some invertebrates, yet it is in birds that it is best studied. As Kalt remarks, the retinal *pigmented epithelium* forms fringes which, under the influence of light, descend to the external limit. In the dark they do not pass (at least in the Pigeon) the middle of the rods and cones.



Figs. 37-49.—Outlines of the shape of the fovea at different levels as seen in sections tangential to the retina or vertical to Fig. 34. x 125.
Fig. 37.—At extreme bottom of fovea. Diam., vert., .008mm.; hor., .016mm.
Fig. 38.—.015mm. from bottom of fovea. Diam., vert., .016mm.; hor., .048mm.
Fig. 39.—.030mm. from bottom of fovea. Diam., vert., .040mm.; hor., .088mm.
Fig. 40.—.045mm. from bottom of fovea. Diam., vert., .048mm.; hor., .132mm.
Fig. 41.—.060mm. from bottom of fovea. Diam., vert., .066mm.; hor., .144mm.
Fig. 42.—.075mm. from bottom of fovea. Diam., vert., .088mm.; hor., .160mm.
Fig. 43.—.099mm. from bottom of fovea. Diam., vert., .096mm.; hor., .208mm.
Fig. 44.—.105mm. from bottom of fovea. Diam., vert., .104mm.; hor., .224mm.
Fig. 45.—.120mm. from bottom of fovea. Diam., vert., .144mm.; hor., .256mm.
Fig. 46.—.135mm. from bottom of fovea. Diam., vert., .176mm.; hor., .288mm.
Fig. 47.—.150mm. from bottom of fovea. Diam., vert., .208mm.; hor., .336mm.
Fig. 48.—.165mm. from bottom of fovea. Diam., vert., .234mm.; hor., .368mm.
Fig. 49.—.180mm. from bottom of fovea. Diam., vert., 300mm.; hor., .432mm.
This is at the level of the inner surface of the retina. The fovea in this specimen is thus .180mm. deep and has a vertical diameter of .3mm. and a horizontal diameter of .432mm.

The purple of the retina is missing, according to Kühne, in the rods and cones of the Hen and Pigeon. It exists in large quantities in the external segments of the rods of the Screech-owl, while the cones are devoid of it.

The cones have variable dimensions and are single or double. At

the end of the internal segment they have a single, oily, colored ball, which is missing in the interior of the accessory cones. In a fresh retina the balls show immediately with their various tints. According to Kalt, Waelchli distinguished four varieties of them: the red balls disseminated over the whole retina; the orange, or yellow balls whose distribution is the same; the greenish-yellow ones seen at the periphery; and the uncolored ones spread in small quantities over all. Osmic acid colors all these balls black. The coloration is particularly intense in the muscular region.

In some birds, the Pigeon, among others, the red balls are more numerous in a portion corresponding to the upper-external quadrant of the retina, than in the rest of the membrane. This color is so marked that it has been called *"the red field."* In the Hen, the part of the retina corresponding to it is yellow.

The height to which the balls are found varies with each tint. The green balls are situated nearest the external surface of the retina, the red come next, then the yellow, and finally the colorless balls.

Within the limits of the red field the green balls are nearest the internal surface and their dimensions are also changed.

The chemical examination of the colored balls of the cones of birds was made by Kühne. A hundred retinas of the Hen were exhausted by alcohol and ether. The fatty material, colored red, gave, with soda, a soap from which could be extracted by petroleum ether a green coloring matter; by sulphuric ether an orange material; with turpentine a deep rose colorant; this last one is, however, insoluble in sulphide of carbon.

Kühne gave the names of chlorophane, xanthophane, and rhodophane to these pigments.

Several thousand retinas of the frog treated in the same manner furnished only a fatty material of yellow color, lipochrin, which is identical with the abdominal fat of this animal. The yellow balls which are found in the pigmented epithelium of the frog's retina have no relation to the xanthophane of birds.

Bipolar cells are very numerous in Birds, a peculiarity also found in the retinæ of Reptiles; a condition characteristic indeed of all retinæ containing many cones.

The *internal plexiform layer* shows a striation in the form of transverse bands, analogous to those of the reptiles.

The ganglion cells are placed in a single layer below the nerve-fibre layer, which shows considerable thickness.

The nictitating membrane or third eyelid. This important organ is really a fold of the conjunctiva. It is situated behind the true or

paired eyelids on the internal or nasal aspect of the eye, whence it extends into the lower conjunctival cul-de-sac. At the anterior or internal part of the sulcus the conjunctival cavity is deepened into a cul-de-sac to receive the third lid. In Man and Monkeys, that lack the retractor muscle, it is represented by the rudimentary organ known as the *semilunar fold.* It attains its most perfect development in Birds, some Reptiles and some Batrachians, in which its extent is sufficient to cover entirely the external surface of the eyeball. Next in importance of development come the Herbivora, then the Carnivora and Marsupials. The Insectivora, Rodents, and the toothless animals have practically no third lid analogue. Among marine animals, only the cartilaginous fish are provided with it.

The third eyelid is composed of a conjunctival fold combined with elastic tissue, vessels and nerves. In the mammifers is also found a plate of hyaline cartilage, often provided with a thick elongation which extends some distance into the orbit.

In Saurians, this plate is replaced by a fibrous one resembling the tarsus of Mammals.

The mucosa, which covers the third eyelid, often contains pigment which may be heaped up near the free margin. In the Frog the third lid has glands analogous to those of the skin. In Sharks its surface is thick and shagreened like the rest of the skin; while in Birds and the Frog the membrane is thin and transparent.

The third eyelid in Birds. Fumagalli has furnished an elaborate description (*Internat. Monatschr. f. Anat.*, 1899, p. 129) of the minute anatomy of this membrane, as found in the Hen and Pigeon. We have not, so far, entirely investigated the nerve and blood supply of the Sparrow, but agree with him that the nictitating membrane is composed of (1) an anterior epithelial layer, (2) a middle connective tissue layer, and (3) a posterior epithelial layer.

The anterior epithelial layer has the appearance of typical pavement epithelium. The deep layers are more cylindrical in form, while the superficial are more flattened and show oval nuclei. Pigment cells begin in the deep cells but get less and less in amount as the surface is reached.

The *middle layer* constitutes the true substance of the nictitating membrane and is largely made up of elastic fibres interwoven with connective tissue fibres. The former are most numerous immediately under the epithelial layer. The middle layer is provided with numerous blood-vessels, nerves, and a number of tubular, solitary glands. Slonaker and the writer have not been able to find the latter in Passer, but we do recognize there glands which are sometimes straight, and

sometimes globular, like sweat glands. Their openings are on the anterior surface of the membrane.

The *posterior epithelial layer* is composed of cylindrical epithelium two and three layers deep. The deepest cells are polyhedral in shape, while the more superficial have long prismatic elements. This layer of the conjunctiva is finally continued as modified anterior corneal epithelium.

According to Fumagalli, the elastic fibres of the third lid run in all possible directions through the connective tissue bundles to form a thick network, which may be resolved into three layers. Furthermore, a bundle of these fibres is shown extending from the base to the apex of the lid. It lies in the deep portions of the connective tissue, directly on the posterior epithelial layer. From this deep, basement or foundation layer of larger fibres there stretch at right angles to it more delicate fibres through the whole width and thickness of the membrane, and terminate in the cells of the anterior epithelial layer.

This strong, deep-lying bundle becomes thicker the nearer one approaches the free border, until it forms two or three fibrous bundles measuring 123 microns wide that eventually becomes part of the tendon of the pyramidalis muscle.

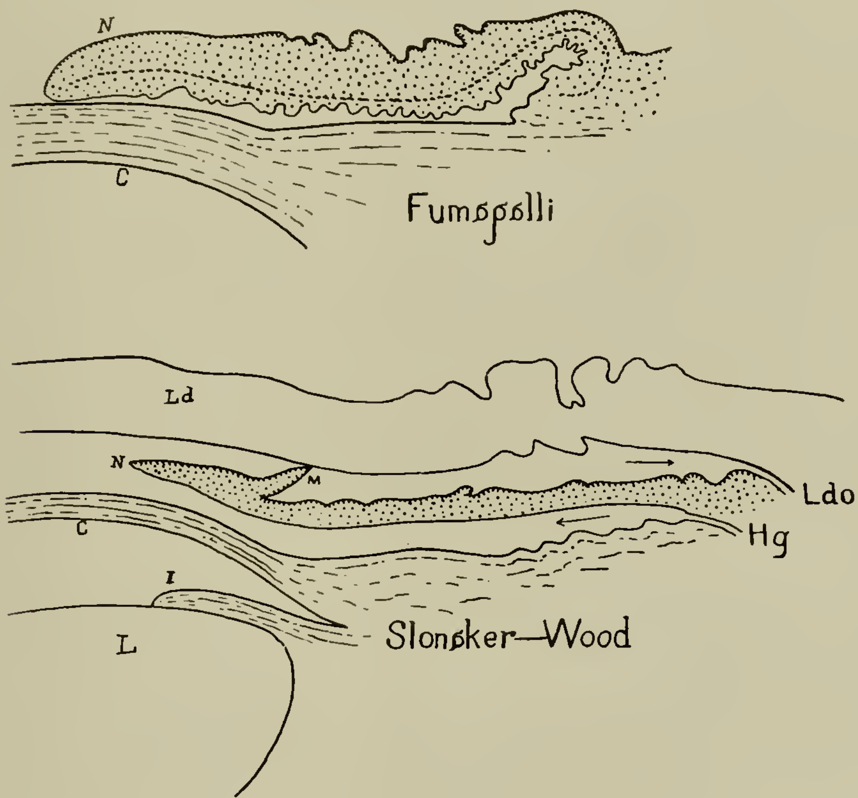
Fumagalli finds that beneath the elastic connective nerve-fibre bundles are so disposed as to form a subepithelial network from which still finer fibrils extend, some of which terminate in end-corpuscles.

Slonaker and the writer, after considerable time spent in an investigation of the subject, have concluded that this duplication of the conjunctiva is a thin, translucent membrane composed of delicate connective tissue interspersed with elastic fibres running in various directions. It has a firm thickened free margin, but no hyaline cartilage cells. This latter provision enables the free border to be closely applied to the cornea, so that when it sweeps over the latter it carries with it some of the fluid secretion of the Harderian gland and thoroughly cleanses and moistens the corneal surface. The presence of elastic fibres gives to the third lid the qualities of a thin rubber band; when put upon the stretch it flies back instantly the moment the pull is released.

The free margin of a portion posterior to it is set with pigment cells, but this marginal pigmentation is much less marked in the Sparrow than in other birds, the Snow Goose and Ostrich, for instance. A section of the third lid at right angles to the free border (see the illustration) shows the latter to be triangular in shape, like half an arrow-head, and to be thrown in folds both on its anterior

and posterior surfaces. Interesting, also, are the basal folds of conjunctiva, something like the folds of transmission of the human conjunctiva, disposed so as to allow of a considerable and rapid extension of the membrane back and forth over the eyeball.

In the study made by Slonaker and the writer on the eye of the Sparrow and other Birds we found Slonaker's *marginal plait* (see cut) not only in numerous sections of the Sparrow's third lid, but in all the other birds so far examined; it is certainly well marked in such unrelated species as the Sooty Tern, the Red-Headed Wood-



Section of the Third Eyelid of a Pigeon, Showing Especially Slonaker's Marginal Plait.

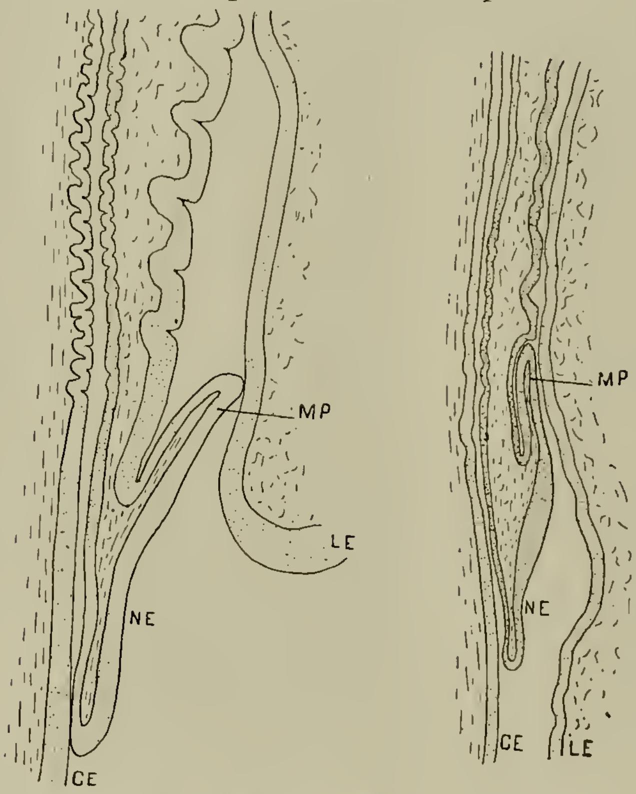
The upper picture is from the work of Fumagalli, the lower as found by Slonaker-Wood.

pecker, and in various Pigeons. Strange to say, Fumagalli (Ueber die feinere Anatomie des dritten Augenlides, *International Monatsschr. für Anatomie and Physiologie,* Vol. 16, p. 129, 1899) makes no mention of this important structure, and, although the whole subject is by him elaborately illustrated by well executed plates, he pictures the Pigeon's accessory eyelid as lacking in the marginal plait.

The pyramidalis muscle in Birds. This muscle is precisely the same in the Sparrow, Hen and House Finch.

The flat tendon of the pyramidalis lies in a groove—almost a tube—on the eyeball. It enters behind the conjunctiva, pierces the lower sac at a point slightly posterior to the median plane of the eye, and is attached mostly along the free border of the third lid as a rope is bound to a sail. The fibres of the tendon are, some of them, also spread out fan-like and are lost in the tissues of the nictitating membrane.

As the posterior-superior attachment of the third lid to the globe is posterior to the vertical plane and well up in the superior cul-de-



Enlarged Camera Drawings Showing the Marginal Plait of the Nictitating Membrane, Both Extended and Compressed. (Wood and Slonaker.)
MP, Marginal plait; *NE*, epithelium of the nictitating membrane; *CE*, conjunctival epithelium; *LE*, lid epithelial lining.

sac, it will be readily seen that the down-and-out pull of the tendon of the pyramidalis must cause the free border of the nictitating membrane to glide over the globe towards the posterior canthus. In ordinary contractions of the muscles the free border is not carried much beyond the posterior sclero-corneal junction, but in energetic contractions it seems to be pulled over to the sclera.

Free border of the third lid of Birds. The histology and physiology of this important external ocular organ of Birds have to do with the cleansing of the cornea, so that it shall be free of foreign matter and continuously moist and transparent. The semi-diagrammatic

cut in the text shows the free margin of the Sparrow's nictitating membrane, both at the centre and towards the upper cul-de-sac. In this situation it preserves its usual structural characters, that of a plate of dense connective tissue covered before, behind and at its border by conjunctival epithelium. In the first figure the slightly pigmented irregular border presents the general outline of the barb of a fish-hook, or of an anchor with one of its flukes cut off close to the shaft. The relations of the processes (really a marginal band) of the free border to the surrounding parts is interesting. It would seem as if the space behind the process or band is obliterated by the pull on it by the pyramidal muscle, when the membrane is swept over the cornea. The corneal detritus (mixed with the Harderian secretion) is then pushed before the shelving margin of the membrane—as a rubber scraper acts, or the sharp margin of the lids in Mammals. On the return journey, when the pyramidalis and quadratus are passive and the elastic fibres are in action, a quite different condition is apparent. The margin of the pectinate fold now rises and presents a dam-like arrangement behind which the corneal debris, tears and more viscid fluid from Harder's gland have meantime lodged. This mixture is now carried or pulled upon the outer margin and external surface of the third lid (instead of being pushed) towards the entrance of the lachrymal canals. The tip or point of the fluke of the marginal anchor and, consequently, the marginate band of the nictitating membrane is, where it touches them at all, in close apposition to the conjunctival lining of the true lids. It will readily be seen that this disposition of the parts greatly facilitates the rapid transportation of lachrymal debris in the direction of the drainage outlet, the true lid preventing fluids from finding their way over the marginal band and onto the cornea.

We have never found this barbed-like, or plicated arrangement at the free border of the nictitating membrane lacking in any of the hundreds of sections we have examined; we cannot understand, therefore, why they are omitted from the drawings and photographs of Fumagalli and others who picture the minute structures of this organ.

Finally, we have not found in Passer the smooth muscle fibres in the free border of the nictitating membrane described by Daenecke (*Inaug. Diss.*, Leipzig, 1899) and Fumagalli (*Internat. Monatschr. f. Anat. u. Physiologie,* 1899, p. 129).

THE LACHRYMAL APPARATUS.

Mammals possess a group of secretory glands at the base of the nictitating membrane, in the angle included between it and the eye-

ball, that correspond to the human caruncle, but the principal lachrymal gland is larger in Man than in the majority of Mammifera. It is situated on the external side, between the superior and external recti. In the Goat, Ophidia, and Chelonia this gland is placed outside the orbit, and projects below the zygomatic arch. In the Sea Tortoise its volume is three times that of the eyeball, in which usual acinous structure gives place here to an aggregate of branching tubes (Pilliet). The other Chelonia and Reptiles generally have, on the contrary, only one gland of little importance.

The Cetacea and the Pinnipedes possess a lachrymal gland on the external side and a gland of Harder on the internal side. The product of the lachrymal secretion is fat, analogous to the Meibomian secretion of land (terrestrial) Mammifera.

It is to be noticed that the glands of Meibomius are missing in these animals, the same as tarses, the eyelashes and the sudoriparous glands. To make up for this, the internal surface of the lids is covered with numerous separate glands.

The lachrymal gland is sometimes composed of two or three masses, to which may be added separate groups of acini.

The excretory apparatus of tears. It is made up in higher Mammifera of the lachrymal sac and of the nasal canal which debouches below the inferior turbinal. The lachrymal points, with the papillæ, are situated in front of the caruncle and represent the opening of channels which join the lachrymal sac. In the Rabbit and the Goat is found, in their place, a yawning slit furnished with cartilage at the edges.

The lachrymal-nasal conduit of the Horse, according to Kitt, has a length of 25 to 26 cm.; the lachrymal channel is 2 cm. long. The lachrymal sac is enclosed by a (venous) plexus and its mucosa is covered by follicular formations. The lower opening is found at the limit of the skin and the nasal mucosa; its diameter is 3 to 4 cm. The canal has several dilations in its route, which reach a breadth of 1 to 2 cm.; while the calibre is otherwise reduced to 1 or 2 millimetres.

The conduit has an analogous structure in the Steer. The lachrymal sac is 5 to 8 mm. in diameter.

In the Dog, the lachrymal points with habitual elliptical contours are visible on the two sides of the caruncle. They enlarge towards their point of reunion. The lachrymal sac, rests upon the lachrymal bone.

The membranous nasal canal presents two varieties: sometimes it is long and opens into the external wall of the nostril; sometimes it is short and opens at the level of the internal surface of the inferior

turbinal. In the latter case its orifice is situated near the end of the bony nasal canal. The two varieties may be found in the same animal.

When the lachrymal gland is not large, the internal excretory apparatus may be lacking. It is so in the Elephant, whose lachrymal gland has the volume of a pea, in the Seal and the Cetacea.

The Bird possesses at the external angle of the eye two large slits placed one below the other. The nasal canal is very much enlarged in its upper portion. It is the same in Reptiles and in the Ophidia, where the nasal canal communicates with the space included between the eyeball and the transparent capsule which covers the latter in front.

The gland of Harder. On the superior-internal angle of the eye there is the gland of Harder, or the deep gland of the third eyelid, whose excretory canal opens below the nictitating membrane. In the Dog it is large, reddish, and goes deep into the inferior cul-de-sac. It is missing in Man, Monkeys, the Cetacea, the Tortoises, the Ophidia, and the Sharks. Habitually, it adheres to the elongation which the cartilage of the third eyelid sends internally. Its color is yellowish, the product secreted is thick. The volume of this gland exceeds quite often that of the lachrymal gland.

By its structure, the gland of Harder belongs to the tubular-alveolar type and is enclosed by a sort of blood sinus. The glandular cells contain many drops of fat and their limit is poorly indicated.

In addition to the preceding *deep* gland there occurs in all domestic Mammifera, at the surface of the third lid, a mucous gland called the superficial gland of the nictitating membrane.

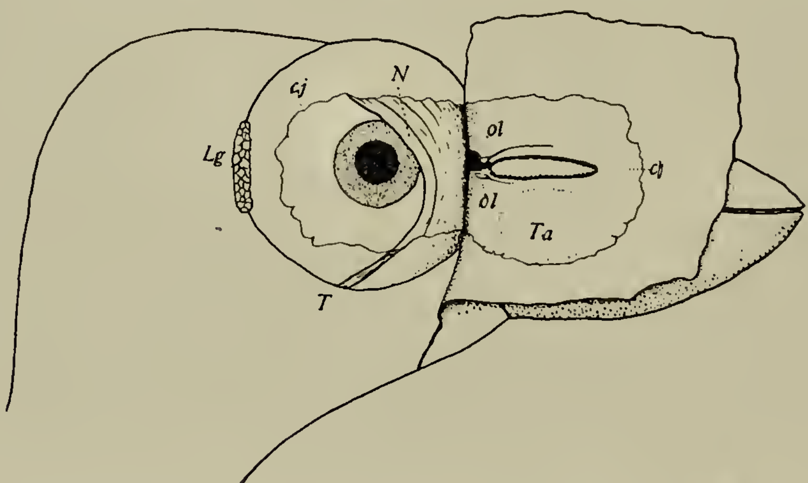
Lachrymal apparatus in Birds. According to Sardemann (*Beiträge zur Anatomie der Tränendruse,* Inaug. Diss., Freiburg, 1887), the lachrymal gland in birds lies in the outer angle of the eye about the equator of the globe. Its size depends more than anything else upon the size of the animal. It has a thin capsule composed of a lobular structure. Inside each lobule one finds a collecting space connected with tubular ducts lined by cylindrical cells with round or flat nuclei. There is no true lachrymal sac.

In the Hen we found the *lower canaliculus* to be the smaller of the two and to be slightly and almost immediately in front of the anterior canthus. Its flattened opening, continuous with the peripalpebral groove, is about 2 mm. wide. The *upper canal,* separated from its fellow by a narrow bridge of tissue, has an opening about twice the size of the inferior opening. It lies appreciably above and still farther towards the front of the beak than the lower opening.

A thin partition of soft tissue divides the two canals for a distance

of 3 mm. when they join to form the lachrymal duct, whose calibre is Sparrow, the Hen has no such well defined lachrymal sac (as in Man), equal to that of the combined upper and lower canaliculi. As in the nor are there true puncta supplied with a suction apparatus, the openings into the tear canals being evidently mere drainage vents. On the other hand, the communication with the buccal cavity is large and unobstructed so that the tears are readily swept into the throat with every excursion of the nictitating membrane or true lids.

The course of the tears, i. e., the secretion mainly of Harder's gland, is quite different from the lachrymal drainage in Man. Although several writers speak of the avian lachrymal fluid as passing into the nose through the lachrymal canals, or of passing into posterior nares,

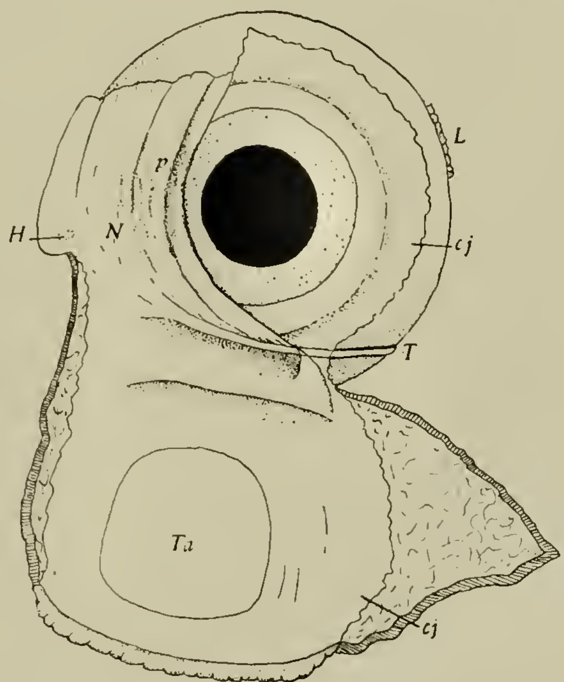


English Sparrow with the Lids Dissected off and Turned Forward to Show the Openings of the Lachrymal Canals, *ol,* on their inner surface; *cj,* conjunctiva; *Lg,* lachrymal gland; *N,* nictitating membrane; *T,* tendon from the pyramidalis muscle to the nictitating membrane; *Ta,* outline of tarsus. x 4. (Wood and Slonaker.)

these statements are misleading, if not untrue. The accompanying figure, representing dissections of several avian species, as well as of the Sparrow, demonstrate that unless one includes the median cleft at the roof of the mouth as an integral part of the avian nares, the lachrymal duct of Birds has but little to do with the nasal passages, but is an isolated tube carried through and past the nasal structures, terminating in and emptying directly into the oral cavity (mouth). The buccal or oral cavity, as is well known, is a receptacle that includes and is not separated from the choana, the pharynx and the larynx.

Hoffman (*Die Tränenwege der Vögel und Reptilien,* Inaug. Diss., Halle, 1882) observed on the lids peculiar grooves leading to the punctal openings, evidently intended as accessory drainage gutters, to assist in directing and carrying the lachrymal secretions into the canaliculi.

The openings of the canaliculi, upper and lower, are not placed on the lid margins at the anterior canthus, but generally open a few millimetres from it by open mouths that are unprovided with marginal connective tissue plates or muscle fibres, as found in Man. Minute shallow grooves, better shown in the Chick, lead from the margin around and close to the margins of both lids that seem to form a gutter-like conduit for the purpose of directing the lachrymal fluid in the direction of the puncta. This might be called *Slonaker's peri-palpebral groove.* These openings are relatively large and communicate each with a correspondingly large canaliculus, which in the Sparrow



Left Eye of the Sparrow with the Lower Lid Dissected Loose and Turned Down to Show the Opening of Harder's Gland (H) Beneath the Nictitating Membrane (N) and the Attachment of the Tendon (T), which Moves the Membrane. x 8. (Wood and Slonaker.)

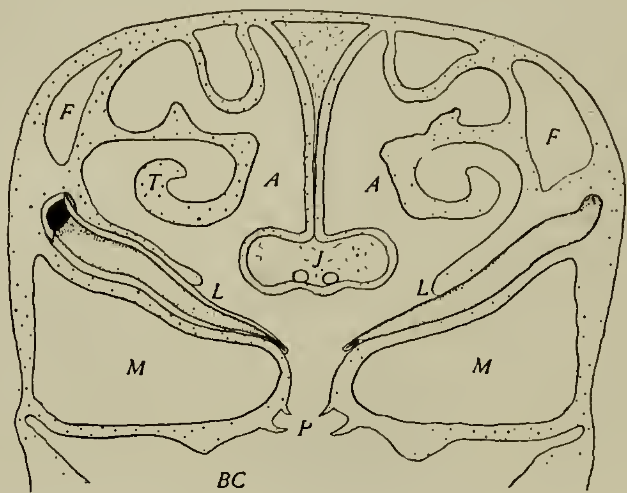
Cj, conjunctiva; *L*, lachrymal gland; *p*, pigment portion of the nictitating membrane (shaded portion); *Ta*, outline of tarsus.

is about 2 mm. long. These join to form a large fibrous tube, lined with epithelium, the lachrymal duct, that runs directly downwards and forwards towards the median line until it opens into the choanal slit, the marginate spines of which direct its contents backwards into the esophageal opening. We found no well-marked lachrymal sac (as in Man) and do not believe that the enlargement at the junction of the two canaliculi is such as to warrant anyone describing it as such, at least in any of the birds we examined.

In the Sparrow a probe 1 mm. in diameter can readily be passed through the lachrymal duct and this probably represents the lumen

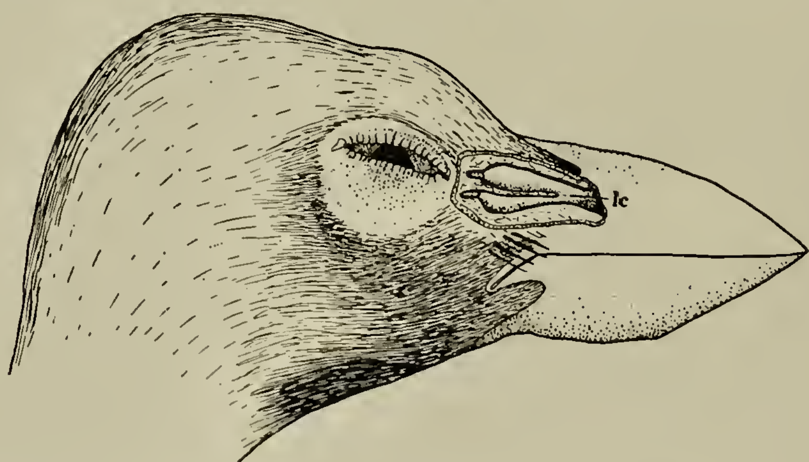
of the tube. The canaliculi are about 1 mm. long, while the length of the common duct may be set down as 3.6 mm.

So far, we have not demonstrated the presence of ciliated epithelium in the duct mucosa.



Enlarged View of a Cross Section of the Head at the Base of the Beak about 2 mm. Anterior to the Eyes to Show the Lachrymal Ducts. The Lower Mandible has been Removed. (Wood and Slonaker.)

AA, Right and left air passages connecting external nares and the buccal cavity, *BC*, through the choana, *P*; *F*, frontal sinus; *J*, organ of Jacobson; *L*, lachrymal ducts which open by horizontal slit-like openings into the choana; the anterior wall of the right duct has been cut away; *M*, maxillary sinus; *T*, turbinals.



Side View of the English Sparrow with the External Walls of the Lachrymal Canals, *lc*, Removed. x 4. (Wood and Slonaker.)

Canaliculi. The openings analogous to the human puncta are irregularly rounded; the upper one being distinctly larger and more patent than the lower. Corresponding to these, Slonaker's *peri-palpebral groove* is deeper, longer and better marked at the conjunctival margin of the upper lid than at the corresponding border of the lower lid.

Physiology of the lachrymal drainage in Birds. As has already been noticed the free margin of the third lid is anchor- or half-spear shaped. The free edge probably pushes before it—scraper-like—the Harderian fluid, thus cleansing the cornea on the contraction of the pyramidalis and quadratus; then at the instant of rest this same secretion, supplemented or not by the lachrymal fluid, is pulled (bucket-like) back and discharged and emptied into the canaliculi.

In the most complete excursions of the nictitating membrane the lower lid edge advances about half a millimetre, while, although there is a simultaneous twitching of its palpebral margin, the upper lid apparently does not come forward at all.

THE CORNEA.

According to Bronn-Gadow, this organ is arranged, as in Man, in much the same manner histologically as the sclera (with which it is intimately connected) except that its fibres are so disposed that they obtain and preserve transparency. At its margins where it is set (watch-glass-like) into the surrounding sclera, it is covered by the conjunctiva.

In the eyes of the large Raptores, this conjunctival overlapping is quite marked; in some instances it covers 2 mm. of the corneal circumference and gives the appearance of a separate organ, and has even been described under the name *ligamentum annulari corneæ.*

Descemet's membrane constitutes the posterior epithelial layer of the cornea and is, histologically, a continuation of one layer of the choroid.

The corneal fibres in most birds run into, interlace and mix promiscuously with the tissues of the sclerotic coat.

Coues (*Text Book,* p. 188) likens the cornea-sclera in Birds to an acorn which has a short, blunt kernel in a heavy shallow cup, or to a thick, old-fashioned watch with a very convex crystal.

It has a marked curvature in animals who look through an aerial medium, since in them it has most to do with the formation of the retinal image. On the other hand, its importance is relatively slight in the case of Fishes that live in a medium whose index of refraction is about the same as their ocular media, the crystalline lens excepted. Plateau believed, after investigations of them, that the flat corneæ of Fishes act like a glass cover to a cup, but Beer disproved this idea after measuring the radial curve of the *medial* portion of the cornea, which he found to vary from 2 to 17 mm. Probably Plateau's error was due to the ease with which the thin cornea of the fish is depressed or flattened.

Generally speaking, however, the periphery of the cornea exhibits a very slight curvature, especially in Water Birds, Batrachians, Chelonians, and Cetaceans.

Its form is almost invariably ovoid. The larger diameter is horizontal even in spherical eyeballs. In the Deer, Ox, Horse, etc., the cornea is symmetrical, and of a triangular shape with the base directed towards the nose.

Among the inferior vertebrates other irregularities are occasionally noticeable. In *Anableps* (see the illustrations) the cornea is divided into two unequal portions by a pigmented horizontal opacity, each corneal half being provided with a separate and distinct pupil. Thus we have two visual organs in a single eye (four in all, hence the specific name of one fish, *tetrophthalmus*), the one adapted to seeing in air (as the fish swims along or rises above the surface of the water in pursuit of aerial prey) and the other for seeing under water.

Analogous organs, devised for seeing both in the distance and close at hand are also found in Insects.

According to Kalt *(Encyclopédie Française d'Ophtal.)* the dimensions of the cornea relative to the globe vary greatly. In Marine Turtles, the Whale, and the Chameleon it is about 1 to 4. Fishes (with relatively and actually large cornea) 1 to 1.3, while in Squirrels, the Rat, the Frog and the Rabbit, this membrane takes up nearly one-half the globar surface. Birds and Lizards have slightly smaller corneæ. although that organ measures half the bulbar diameter, except Night Birds, whose relative dimensions are 1 to 1.8. Except Ruminants, the Mammalia generally have corneæ whose relative measurements are 1 to 2. As a general rule, large corneæ are found in animals that live largely in a dim light (Fishes) or that go about mostly at night, Owls, for example.

The cornea of Birds. Its structure offers nothing peculiar, being essentially the same as in Mammals; but its shape is remarkable. Always very convex, it is sometimes still more protuberant, being elongated into a sort of cylinder, with a hemispherical top. This tubulation is very great in nocturnal birds of prey—the Owls, for example. The alteration of shape that the cornea is capable of in Birds is most singular.

As a rule, the *corneal diameters* equal the radii of the globe at the equator. They are, however, longer in Owls, Herons and Buzzards; shorter in the Ostrich, Swan and Heron. The Owls have the largest corneæ.

The cornea of Birds is, as compared with that of mammals, very thin. Bowman's membrane is distinctly present (Zietzschmann). The

anterior epithelium is thin but thicker at the edge of the conjunctiva. In the Pigeon it is four to five layers thick at the margin. The ciliary muscle is attached to a spur of the inner lamella of the cornea.

Slonaker and the writer did not find it easy to take measurements of the Sparrow's cornea. During life, its periphery is completely hidden by the lids, and even at the outer canthus, where the sclera is exposed, the limbus is pigmented and forms no contrast with the dark lid borders. In the preserved material and in sections, on the other hand, these measurements may be misleading. However, by selecting the most perfect sections and making many observations with calipers and by comparisons, it was found that opposite points at the sclerocorneal junction are separated about 3.55 mm. in all directions. In other words, the Sparrow's cornea, when the accommodative apparatus is inactive, is a regular segment of a sphere. The evidence of the ophthalmometer also points to this conclusion.

ANTERIOR CHAMBER.

The *depth of the anterior chamber,* i. e., the distance of the lens from the cornea, varies greatly. In Amphibia and Fishes the spherical lens is almost in contact with the cornea. It is widely separated, on the other hand, in Birds of Prey, in which the depth of the anterior chamber may be 8 mm. It is barely 5 mm. in the largest Mammals.

The anterior chamber is shallow in the Sparrow; at the antero-posterior axis its depth is about 0.55 mm.

Sclerotic or sclera of vertebrates. This membrane, which forms the chief protective coat of the eye, is generally continuous with the fibrous covering of the optic nerve of vertebrates. This is well shown in Cetaceæ, where the two envelopes reach a very considerable thickness. The illustration shows both the thickness of the sclera and external covering of the optic nerve in the Whale, which measures behind, 45 mm. to be reduced at the sclero-corneal junction to from 2 to 4 mm.

THE SCLERA.

The sclera in Monkeys and the higher vertebrates closely resembles that of Man.

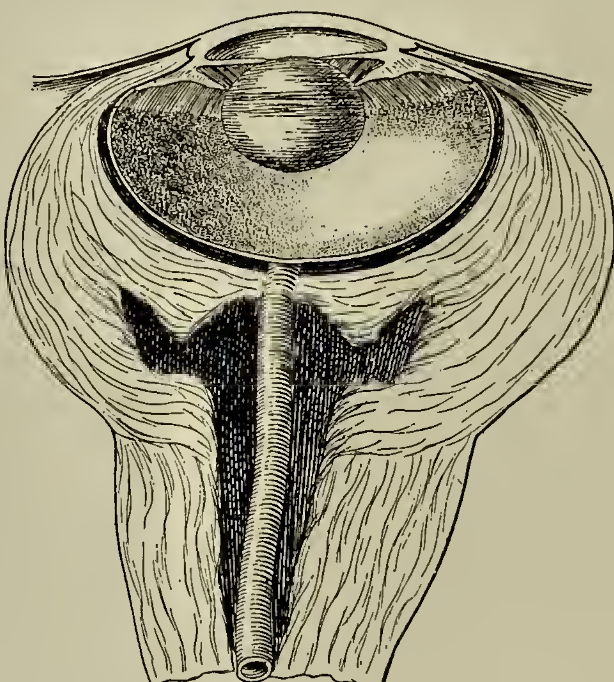
In many Mammals the sclera at the corneal border often contains pigment granules, as is shown in the Hog, Sheep, Turtle and Chimpanzee.

In some Vertebrates, apart from the Mammalia, the otherwise purely fibrous structure of the sclerotic is modified by the insertion of *cartilaginous* and *osseous plates.* With the exception of the Sturgeon, the ocular wall of Fishes is thinner than in Mammals.

Langhans describes three types of sclerotic in Fishes. The first is those whose structures are entirely made up of connective tissue, as in Petromyzon; the second comprises those sclerotics made up of fibrous tissue and cartilage, as in Selacians; third, sclerotics composed of connective tissue, cartilage and bone, which includes the great majority of the Teleosteans.

The sclera of Birds is particularly interesting and will receive special notice in this section.

In Birds the sclera is a thick, strong, tough membrane of a glistening, livid, or greenish-blue color. Three sclerotic coats or layers, differing from each other a little in texture, may be demonstrated by careful

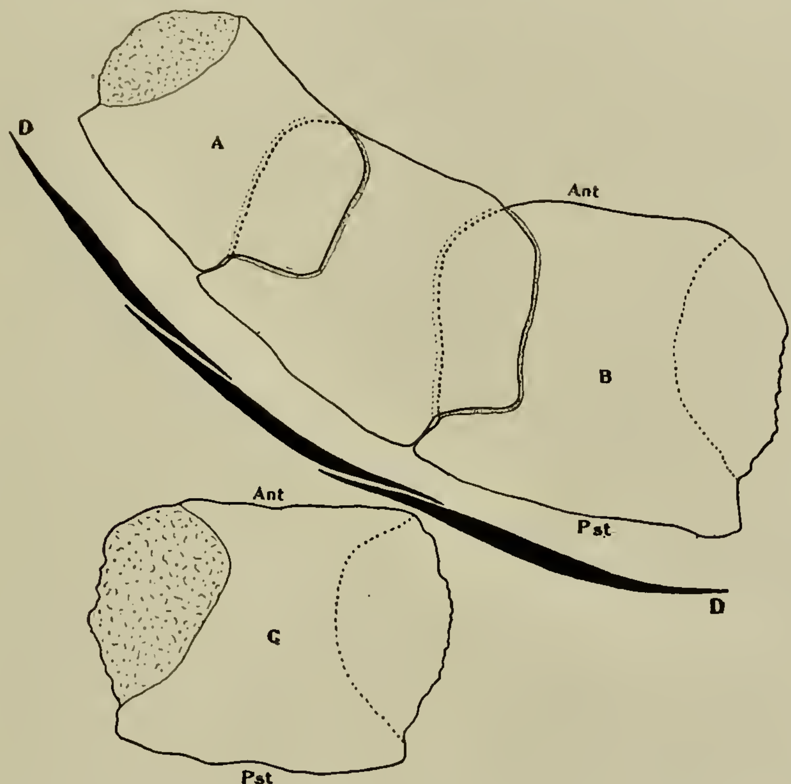


Eye of the Whale, Showing the Enormously Thick Sclera and Dural Covering of the Optic Nerve.

dissection, though on superficial examination the sclerotic presents itself as a single, homogeneous tissue. The anterior *osseous plates lie between the outer and middle sclerotic coats,* anterior to the greatest circumference of the eyeball. They extend nearly or quite to the edge of the cornea. They are fifteen or twenty in number, of an oblong, quadrate shape, broader behind, tapering toward the cornea and so disposed as to form a complete bony circlet around the latter. Collectively, they enjoy some little motion, their anterior margins advancing and receding with the varying convexity of the cornea; but they can never "wabble," being firmly bound to each other by the continuation of the sclerotic coats between them.

Bony plates in the bulbar coats. Osseous plates or *sclerotals* are best developed in Birds. They are of two kinds, but of unequal importance. The first consists of a bony circlet (like that found in the Teleostean Fishes) shaped like a horeshoe, which surrounds the optic nerve. It is seen in the smaller Warblers, and in Woodpeckers.

The second variety, already referred to, is much more important. They are called *sclerotals* or the *anterior sclerotic ring.* They are

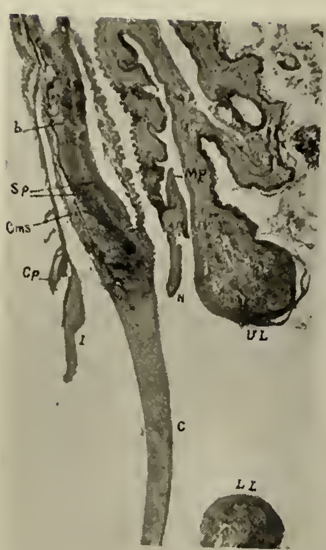


Camera Drawing of the Sparrow's Eye, Showing the Scleral Plates. (Wood and Slonaker.)

A, B, The scleral plates showing how much they overlap and their variation in size; *A,* is from the anterior or nasal side of the scleral ring; *B,* from near the dorsal part; *Ant,* anterior and *Pst,* posterior edges; *D D,* section at right angles to the surface of the plates to show the method of overlapping; *C,* an isolated scleral plate from the temporal side of the scleral ring; *Ant,* anterior and *Pst,* posterior margin.

inserted in the scleral wall corresponding to the intermediate or intercalary zone, of which they constitute a kind of framework, presenting the appearance of a funnel, often quite deep, which gives the peculiar shape to the eyeballs of Night Birds. The Pigeon, the Magpie, the Crow, the Ostrich, and other birds have an anterior scleral ring whose posterior margin *overlaps* the anterior border of the cartilaginous segment and further protects the back of the eye. Its anterior margin stretches forwards to the sclero-corneal junction.

The sclerotic ring is, in addition to the bony plates, made up of



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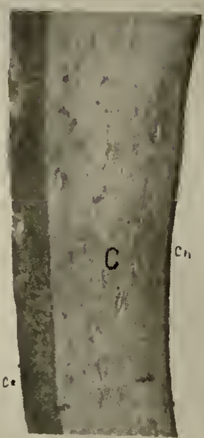

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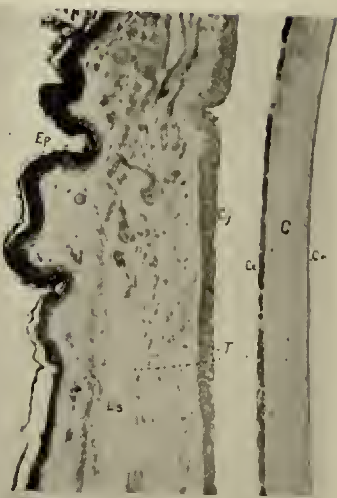

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Magnified Portions of the Anterior Part of the Vertical Section of the Eye. (Wood and Slonaker.)

b, Showing an apparent break in the scleral plates where a basilar vein pierces these plates; *C*, cornea; *Ce*, corneal epithelium or conjunctiva; *Cj*, conjunctiva; *Cn*, endothelium of the cornea; *Cp*, ciliary processes; *Cms*, ciliary muscles; *Ep*, epithelium; *F*, feather follicle; *Ll*, lower lid; *Ls*, lymph spaces; *M*, depressor muscle of the lower lid, striated appearance shown at *M; Mp*, marginal plate of *N M; Sp*, scleral plates; *T*, tarsus of the lower lid, its thickness indicated by the two lines; *Ul*, upper lid.

Fig. 166.—Margin of the lower lid as indicated in Fig. 164-166. x 250.

Fig. 167.—Portion of the lower lid as indicated in Fig. 164-166, showing upper portion of the tarsus. x 250.

Fig. 168.—Portion of the lower lid as indicated in Fig. 164-166, through the depressor muscle of the lid. x 250.

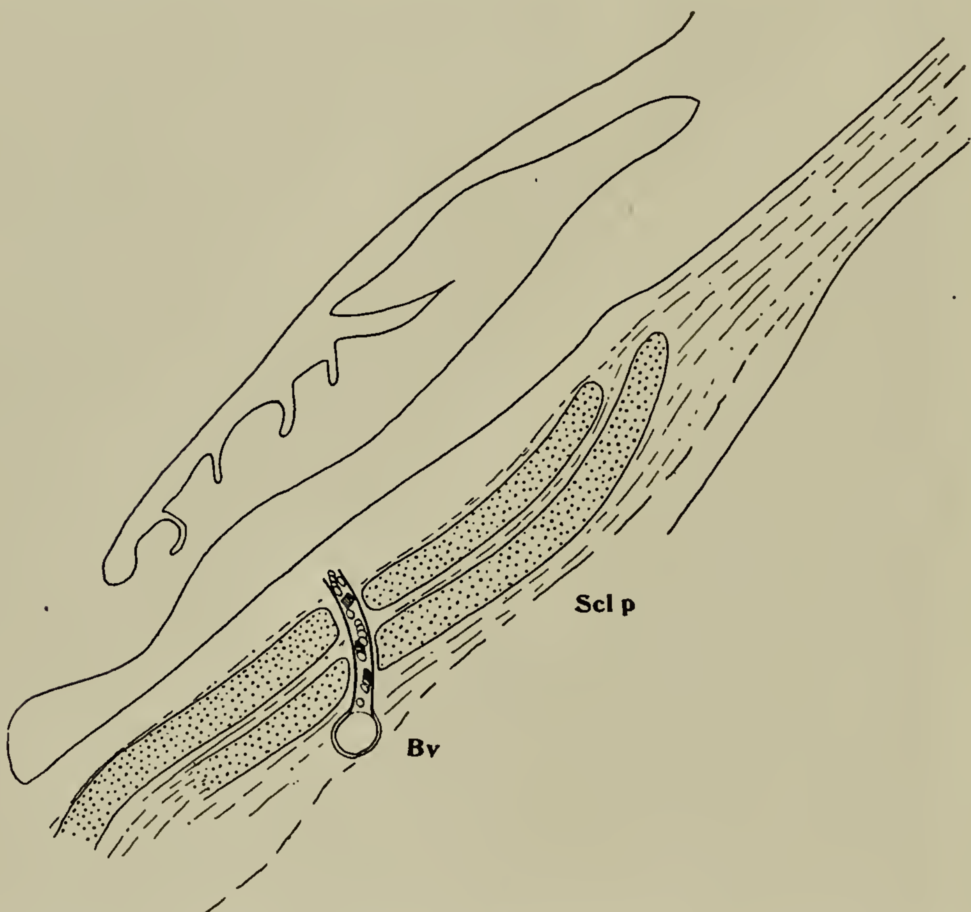
Fig. 169.—Portion of the cornea as indicated in Fig. 164. x 250.

Fig. 170.—Vertical section through the upper lid, showing the relation of the parts and the sclerotic plate pierced by a blood-vessel. x 40.

compact tissue that in the Ostrich contains nerve fibres, blood-vessels and pigment cells resembling those one finds so abundantly in the connective tissue of the sclera and ciliary body.

The scleral ring is also found in many reptiles; in Turtles and Lizards, but is absent in Crocodiles, Snakes and Fishes, unless we recognize as such the two bony plates inserted at the superior and inferior corneal margins of the Sturgeon.

The bony scleral ring is very poor in blood-vessels. In all vertebrate orders, however, there is at the circumference of the cornea a well-



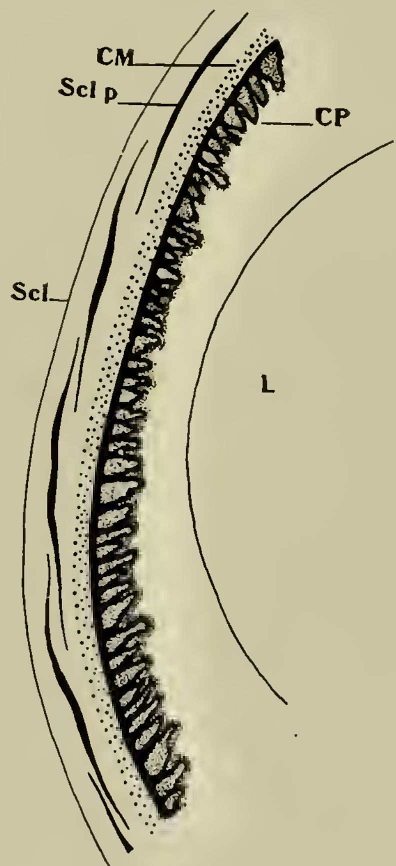
Enlarged View of a Section Through two Scleral Plates (Scl p), in the Sparrow's Eye, Showing the Passage of a Blood-vessel (Bv) directly Through Them. (Wood and Slonaker.)

developed zone of vascular loops. These vessels are of two kinds, superficial and deep. The *deeper vessels* are better developed in the lower animals than in man. They are usually an arteriole and two accompanying veins, following the course of a nerve fibril. In the Calf and the Sheep they may invade the cornea. They are also found in the Antelope, Horse, Dog, many Birds, Snakes, and Fishes, but seem to be absent in the Rabbit and in Amphibia.

The *posterior sclerotic plate* in Birds has been described by Leuckart, Nitzsch and others, who claim that this semicircle around the nerve entrance is, *when ossified*, confined to Caprimulgi, Pici and Passeres. Nitzsch has also found in or near it the insertion of the *musculus pyramidalis* to what he terms the *os tuberculare*.

This scleral plate is also said to be constant in the Sparrow, to be of mixed cartilage and bone, to be well developed and almost to surround the nerve. However, the *os tuberculare* has not been discovered by Slonaker or the writer in *Passer domesticus*.

It may be added that the Sparrow has only two overlapping sclerotals, which are *all* bone. In this bird, also, the posterior margin of



Portion of an Equatorial Section Through the Ciliary Region, Showing the Ciliary Muscles, CM; Ciliary Processes, CP; Lens, L; Sclerotic, Scl; and Scleral Plates, Scl p. x 40. (Wood and Slonaker.)

Average width of plates, 1.2mm. Average length of plates, anterior margin, .65-.75. Average length of plates, posterior margin, .90-1.00.

the anterior scleral ring overlaps the cartilaginous layer of the sclera about one-tenth of the length of the former.

Indeed, it may be stated pretty positively that the *cartilaginous ring about the optic nerve entrance* in the Sparrow is not ossified. It is plainly a simple thickening or development from the cartilaginous

layer, which, cap-like, surrounds and gives additional strength to the posterior two-thirds of the avian globe. It is not, as described by some writers on certain other birds, a cartilaginous or bony plate set, horseshoe-like, around the optic nerve. In Passer it is a complete or nearly complete ring, which hardly corresponds to the term horseshoe, given to it by Leuckart, Nitzsch and others.

Canal of Schlemm. Circulus or sinus venosus Schlemmii. As Angelucci (*Archiv f. mikr. Anatomie,* Vol. 19, 1881) pointed out, this canal is situated in Birds at the sclero-corneal junction at the margin of the fibres of the ciliary muscle—much as in Man. Lauber found about it an arterial plexus and thought this arrangement to be peculiar to Birds.

THE CRYSTALLINE LENS SYSTEM IN VERTEBRATES.

This organ is found in all vertebrates. In Fishes it is alone concerned in the focusing of the retinal images, while in Birds this function is largely performed by the cornea. It is attached to the lens by the zonula of Zinn.

The *shape of the lens* is nearly spherical, with slight flattening of its anterior surface in Amphibia, Fishes, Chelonians and Reptiles. However, in the Chameleon, the Viper, and the Adder the contrary is the case. It is more lenticular in Birds and Mammals, except such water animals as Aquatic Birds, Whales, the Seal and the Herbivora, and in the Primates shows a flattened figure, the antero-posterior diameter being less than half its diameter. As in Man, most of the higher vertebrates present the posterior surface of the lens with a greater curve than the anterior.

Size of the lens. It is very large in Fishes. The little Gecko has a lens six times larger than that of the Lizard. The Whale's lens measures 13 mm. in thickness by a diameter of 16 mm., which after all is comparatively small if one recollects that the whole eye is 7.5 cm. long and 12 cm. wide.

The largest lenses, *relatively,* are found in the Hare, Mouse, Rat, Squirrel, the lenticular body of the last being larger than that of the Hog. The smallest vertebrate lenses, comparatively speaking, are those of Man and the other Primates.

Emmert (*Zeitschr. f. vergl. Augenheilk.,* 1886) compared the relative volume of the lens to the size of the eyeball and found that it was in the Horse 6 to 100; Sheep 7.6 to 100; Dog 7.7; Cat 10 to 100; Rabbit 8 to 100, and Man 4.2 to 100.

The *index of refraction* of the piscian lens is greater than that of

glass, 1.60. In Man and other Mammals it is about 1.40. The lens of Fishes forms a dry hard mass, while in Birds it is much softer, and this arrangement in the latter class of animals is intended, according to Kalt, to permit of easy and rapid changes of form necessary to the instant accommodation of Birds.

In the bird, the ribboned appearance is very marked; it is so apparent among the fish that one has difficulty in recognizing the contours of each fibre. In a section taken through the plane of the equator of the lens, these ribbons are superimposed in the form of piles limited at the right and left by a zigzag border and the neighboring piles, adhering to each other by a sort of dove-tailing. It is not unusual to find irregularities in connection with a certain number of elements in the piles, whence it may be concluded that the fibres of the crystalline lens are plastic elements and may be deformed by lateral pressures, which they withstand. Finally, sometimes these piles of fibres are forked and form two separate columns.

The mass of crystalline lens consists of concentric layers of fibres, each of which is supplied with a core (nucleus) ; this last is especially apparent in the equilateral layers, the last to be found. These fibres are made up of long flat ribbons, hexagonal in section. Their dimensions vary not only from one animal to another but even in the different layers of the same lentil. In general, however, it may be said that they become flatter the further down the animal scale one goes.

Rabl (*Ueber den Bau und Entwicklung der Linse,* 1900) distinguishes four types of lens in Vertebrates.

The *first class* includes those in which both anterior and posterior surfaces are very convex, and the anterior epithelium extends posterior behind the equator, as seen in amphibian larvæ and in Fishes.

The *second class* exhibits the two surfaces of unequal curvatures, as in some Snakes, Amphibians and Mammals.

In the *third class* the two surfaces are irregularly curved; the limits of the epithelium are found to be far behind the equator, as seen in all Birds and most Reptiles.

The crystalline is spherical in the *third* class, and the epithelium ends at the equator in the Viper and Adder.

Regeneration of the lens. The lens has never reappeared after extraction in any of the higher vertebrates, yet we know that wounds of the lens of the Rabbit and in Fishes close without leaving a trace of the trauma. In the Amphibian Triton, Bonnet noticed as long ago as 1779 that the lens grew again after removal. As soon as the crystalline is removed from the eye of Salamander larva the cells of the epithelial layer behind the iris at the border of the pupil begin

to proliferate. A vesicle is now formed which becomes detached by atrophy of its pedicle and a lens formation goes on precisely as the original lens was developed from the ectoderm.

Suspensory ligament of the lens. Except in Fishes the zonula of Zinn or suspensory ligament is formed by a collection of filaments that extend from the ciliary body of the equator of the lens, as in Man and Monkeys. The circumference of the lens presents a series of ridges alternating with depressions. The zonular fibres are attached to the ridge-like projections. Between the ora serrata and the margin of the lens the hyaloid membrane is reinforced by the radiating fibres of the zonula of Zinn. According to Kalt (*Encyclopédie Française d'Ophtal.* III, p. 855) these fibres are very easily seen in Birds, but neither Slonaker nor the writer has been able to distinguish them with any approach to ease in hundreds of sections of Passerine eyes; indeed, the zonular fibres are very poorly developed in Birds and they are often mistaken for the filamentary framework of the vitreous in that neighborhood. It is still more difficult to conceive of them as taking any effective part in the act of accommodation by exerting tension on the intermediary and firmer Ringwulst, sufficient to effect any appreciable change in the form of the lens; they are too delicate and the supporting ring of the lens, whose shape they are supposed to change, is too hard.

In Birds the zonular fibres are arranged in a recti-linear band, attached to the equator of the lens by which it is joined to the periphery of the retina. This union opposes in its turn the displacement towards the base of the lens brought about by the contraction of the muscle of the campanula of Haller. A further description and illustration of these organs will be found under **Accommodation** in the eyes of Fishes.

Form and volume of the crystalline lens. The eyes of Fishes and Batrachians have almost spherical lenses; in Mammals and Birds the lens is more or less flattened, its two surfaces being unequally convex, the posterior face generally more curved. This is reversed only in a few Carnivores, such as the Cat. The non-spherical lens is a surface of revolution, even for eyes whose globes have very different diameters in different directions. For example, this is the case in those whose horizontal, vertical and saggital lens diameters are respectively 145 mm., 129 mm. and 107 mm. As Koschal has shown, for certain domestic animals, the vertical diameter is less by 1/20 than the horizontal diameter.

The relation between the volume of the lens and the capacity of the

aphakic eye is very variable in the animal series, as shown in the following table:—

Table (*Encycl. franç. d'ophtal.*, Vol. III, p. 920).

	Volume of the Crystalline Lens in cc.	Intraocular Capacity in cc.	Relation 1 to	Observer
Man	0.25	4.5	18.0	Emmert
Horse	3.29	40.0	12.1	Matthiessen
Dog	0.50	4.1	8.2	Emmert
Rabbit	0.25	2.5	10.0	
Whale	5.01	123.0	24.6	Matthiessen

The index of refraction of the crystalline lens increases on leaving the cortical layer where it has almost the same value (1.385) in all animals, to the centre where it varies a great deal with the species.

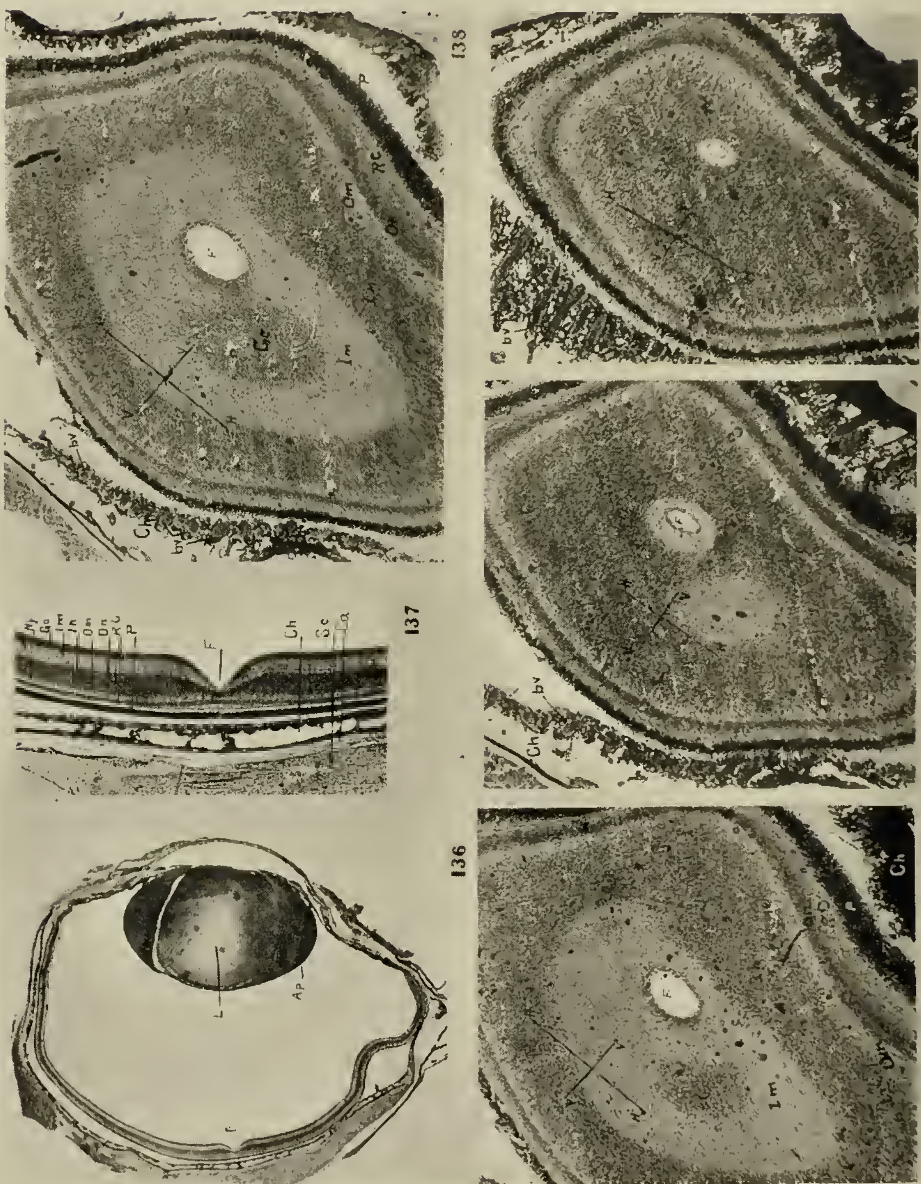
The difference between the central index and the cortical index of the lens mass in Vertebrates is greater in Fishes and Mammals. In this regard the crystalline lens of the Whale approaches that of Fishes.

The lens-system in Birds. According to Ellenberger-Zietzschmann *(loco cit.)* the lens of Birds shows a marked difference from that of Mammals. It possesses a firm, almost spherical central body, surrounded by an annular covering which is thickest at the equator. This ring is composed of more or less cylindrical cells. Slonaker and the writer agree with Ritter (*Archiv f. Augenheilk.*, 1900, p. 370), Henle and Rabl that between the Ringwulst and lens there is a space filled with a slimy (lymph?) fluid which plays a part in accommodation. C. Rabl divides this annular mass or Ringwulst into three parts, anterior, middle and posterior, of which the anterior portion nearest the cornea, is not sharply defined. From the pole of the equator the epithelial cells become gradually longer and form hexagonal prisms. In the equatorial region these cells all end in bulbous expansions at their inner ends.

The medium layer reaches to the back of the equator, the fibres are very long and spindle-shaped, and they also end in club-like expansions.

The posterior layer represents the connections with the true lens fibres. Here the cells are broad and short spindles, and the bulbous terminations seen in the other fibres are lacking. They finally pass over into the lens fibres as in the lenticular epithelial of Mammalia.

The cells of the annular mass possess a few nuclei situated at their outer terminations; in the equatorial region they form more than one row. The posterior cells of the annular covering are arranged as in



138 137 136 141 140 139

Ap, Annular pad of the lens; *bv*, blood-vessels of the choroid; *Ca*, cartilage of the sclerotic; *Ch*, choroid; *F*, fovea; *Gc*, ganglion cell layer; *H-H*, horizontal plane; *Im*, inner molecular layer; *In*, inner nuclear layer; *L*, lenticular portion of the lens; *Nf*, nerve fibre layer; *Om*, outer molecular layer; *On*, outer nuclear layer; *P*, pigment layer; *RC*, rod and cone layer; *v-v*, vertical plane. (Wood and Slonaker.)

Fig. 136.—Horizontal section of the adult eye through the center of the fovea and pupil. x 10.

Fig. 137.—Enlarged view of the fovea of Fig. 136. x 40.

Fig. 138.—Section tangential to the fovea at the level of the inner edge of the inner molecular layer, showing some of the ganglion cells and the oval shaped fovea surrounded by ganglion cells. x 50.

Fig. 139.—Section tangential to the fovea through the central portion of the inner molecular layer. x 50.

Fig. 140.—Section tangential to the fovea through the inner part of the inner nuclear layer. x 50.

Fig. 141.—Section tangential to the fovea through the middle of the inner nuclear layer near the bottom of the fovea. x 50.

Mammals, and the single fibres are similar to those in Man except that they are broader and thinner. The nuclear zone of the lens is arranged as an arc parallel to the outer surface of the lens mass from about the level of the equator backward, after which they gradually disappear. Rabl has drawn attention to the fact that the annulus of the Pigeon is not of equal mass about the equator and that, generally, a thick and a thin hemisphere may be distinguished, although the difference between them is small. From measurements of sections of Sparrow's Ring and lens we have reason to believe that this holds true.

The *lens capsule* surrounds both the annular mass (Ringwulst) and the true lens. In the Sparrow we have not been able to demonstrate any ring fibres in the artic circles (in the antero-posterior axis) about the lenticular poles, i. e., between the capsule and the true lens in that neighborhood. Histogenetically, there is no difference between the fibres of the ring and those of the lens proper. On the second day of embryonic life the fibres of the passerine lens resemble very closely the adult fibrillæ of the annular mass.

According to most authorities (a statement in which we cannot concur) zonular fibres arise from the epithelium of the orbiculus *(pars ciliaris retinæ)* and more or less cover them. These fibres are said to be inserted in the lens capsule.

In the Sparrow the lens and annular mass measure as follows: the horizontal-equatorial diameter of the entire ring-lens mass is 3.7 mm.; the vertical diameter is 2.40 mm. The horizontal diameter may be divided into that of the annular mass on either side, 0.58 mm., making for the two sides 1.16 mm. This leaves 2.54 as the horizontal diameter of the lens itself.

The *intralenticular space, cavum lenticuli,* or, as Slonaker calls it, the *lenticular cavity,* has received relatively little attention at the hands of comparative histologists. In the Sparrow it is well marked and constant. It extends entirely around and below the equator of the lens, is on section pear or club-shaped, irregular in outline and, as we have found it, almost entirely filled with a secretion which is essentially lymph or at least lymphoid. In passerine individuals the space varies in all its measurements and in different sections of the space.

Carl Rabl, to whose remarkable studies of the lens (*Ueber den Bau und die Entwicklung der Linse:* II Teil, Reptilien und Vögel, *Zeitschr. f. wissenschaftl. Zoologie,* 67, 1899, p. 257) we are much indebted, draws one's attention to the regular disposition of the avian (Pigeon) ciliary processes about the annular equator, to the markings (Impressionen) on the capsular surface of the ring and to the undulations in the fibre arrangement corresponding to these. He thinks that we are

justified in believing that the ciliary processes in accommodation press upon the exterior of the ring in the exact points indicated and this pressure is communicated to the lens with the result that its shape is changed, especially antero-posteriorly.

Slonaker and the writer have not been able to find the lower ciliary fibres (zonula of Zinn) depicted by Zietzschmann either in dissection with the binocular microscope or by any staining method. It is doubtful that the zonular fibres are, as in Man, a kind of tendon attached to the lens capsule, such as is seen distinctly enough in Mammals. The exact relation of the fibrils, or rather membranous bands, to be seen by the aid of certain stainings and a high-power lens to the lens and other tissues of the ciliary region, has occupied much of the writer's attention in the case of the Sparrow. The impression resulting from examinations of many sections is chiefly that of von Lenhossék as seen in the chick (Entwicklung der Zonularfasern nach Untersuchung am Hünchen, *Archiv f. mikr. Anatomie*, 1911 Vol. 77, p. 280); that is to say, (1) the so-called zonular fibrils are in the Sparrow very delicate and much less developed than in Mammals. (2) If their purpose is to hold the lens in a taut or tense condition, they are assisted in that function by the ciliary processes whose intimate attachment with or close relation to the capsule of the annular mass is easily demonstrated. (3) The so-called zonular fibres, if they have any real existence, are as much developed from the hyaloid membrane (well shown in the Sparrow) as from the ciliary processes or orbiculus. We have not been able to discover any penetration of the zonular fibres into the cells of the *pars ciliaris retinæ* of the Sparrow, the same observation having been made by von Lenhossék in the case of the Chick. Consequently, we are unable, so far as we have gone, to discover in the Sparrow any arrangement analogous to the human zonula of Zinn. For the present it seems from the morphology of the organs in the ciliary region that accommodation in the Sparrow is accomplished by the help of the three divisions of Crampton's muscle in causing a to-and-fro movement of the true lens, in the direction of its antero-posterior axis, and by a constriction and consequent lengthening of that axis by pressure of the ciliary processes on the Ringwulst, conveyed to the true lens. For the moment we have *sub judice* the parts played by Brücke's muscle and Müller's muscle, and with it the questions as to whether the antero-posterior axis of the whole eye is affected by the action of Crampton's muscle and whether the pressure exerted by the margins of the pupil under the influence of the powerful constrictor changes at all the curvature of the lens. If we were at this stage of our investigations to venture a statement,

it would be that the true lens being much firmer than the Ring, the pressure upon the latter is much more likely to be expended in pressing

Horizontal Section Through the Center of the Lens and Fovea of the Eye of the Adult English Sparrow. Outlined with Camera. x 32½. (Wood and Slonaker.)

1, Nerve fibre layer; 2, nerve cell layer; 3, inter-molecular layer; 4, inner nuclear layer; 5, outer molecular layer; 6, outer nuclear layer; 7, rods and cones; 8, pigment layer, a, artery; B, bony portion of the orbit; Br, Brücke's muscle; C, Crampton's muscle; Ch, choroid; Co, cornea; Cj, conjunctiva; Cp, ciliary processes; Cs, canal of Schlemm; Ep, epithelium; F, feather follicle; Fov, fovea; Hg, Harder's gland; I, iris; L, lachrymal gland; Ld, lower lid; Ls, lenticular portion of the lens; M, Müller's muscle; Mp, medium plane of the head; N, nerve; Nc, nictitating membrane; O, orbicularis muscle fibres of the lid; Ob s, superior oblique muscle; Pc, pars ciliaris retinæ; q, quadratus muscle; R ex, rectus externus; R int, rectus internus; Rp, ring-like pad of the lens; Rs, rectus superior; S, scleral plates; Scl, sclerotic coat, the dotted part shows the cartilage portion; Sc, secretion in the lenticular cavity; Sp, artefact space between the choroid and retina due to shrinkage in the hardening processes. x Relative equatorial diameter of the human and sparrow's eyes.

out its fibres than in changing the shape of the more resistant true lens, and that in consequence of this fact a forward movement of the

whole lens mass and an increase in the axial measurements would be the result. If conditions were reversed, i. e., if the envelope of the lens were the harder and more resistant it would be possible to conceive of outside forces changing its shape, but the theory of the transmission of pressure through a soft body to change the form of a hard nucleus is poor mechanics. Finally, we have not completed our experiments made during life, with miotics, cycloplegics, the skiascope, the ophthalmometer, the ophthalmoscope and such procedures as the freezing of von Pflugk to assist in clearing up these mysteries. The circumlental space that Ritter and Henle described as existing between the body of the lens and the Ringwulst is easily seen in the Sparrow. The slimy fluid with which this space is filled can also be demonstrated in this bird. Slonaker believes this space and its contents to be an embryological remnant of the lens vesicle.

Ciliary processes and the lens capsule. Ischreyt (Zur vergleichenden Morphologie des Entenauges, *Archiv f. vergl. Ophth.*, III, 1912, p. 48) finds that in the case of *Anas boschas* a frontal section showed 104 ciliary processes in contact with the perilenticular capsule, and that in the space of 1 mm. of the lens mass periphery 6 to 7 could be counted. In the case of *Harelda hyemalis* (Eisente) a frontal section disclosed in the same situation 75 ciliary processes well provided with connective tissue, of which 4 to 5 were counted in 1 mm.

This act of compression and elongation of the antero-posterior axis is an indirect one; the ring taking no direct part in the refractive effect. This is abundantly proven by the fact that the iris, even in the widest expansion of the pupil covers the ring area.

Rabl concludes that in Birds the proportion of the ring mass as contrasted with the whole lens-ring, is in direct relation to the velocity of their flight. For example, the ring in the lens of the Hawk comprises more than one-third and the Swift more than one-half the total mass of their respective lens systems. In the Sparrow the proportion is as 1 :3.197, so that while this calculation does not contradict, it does not particularly corroborate Rabl's contention.

The Sparrow belongs to the slow-flying birds and certainly does not exceed the flight of the Pigeon, which Jackson (quoted by E. J. Marey, *Le vol des oiseaux*, 1890) puts down 27 metres per second, while the Swift is estimated to cover 88 metres in the same space of time.

Franz thinks in Birds differences in the lens mass of species depend more upon the size and thickness of the ring-pad than upon its internal structure, as far as is actually known.

The asymmetry is greatest in Cypelus, but is also noticeable in other species.

The development of the ring-pad is unequal in respect to breadth and height. It is rather narrow, for instance, in Phœnicopterus and Gallinula.

The Apteryx and Cercopsis have the thinnest ring-pad, which is almost invisible to the naked eye. Then follows Struthio, Uria, Urinator and Ardea—it is represented by the most external small strip. In Ardea it rests mostly upon the margin of the distal surface of the lens; it, as well as the epithelial margin, lies distal from the equator of the lens.

It is thin in relation to the size of the lens in the Owl and Podargus. Then follow the Parrots, next the majority of birds and next the diurnal birds of prey.

Especially thick is the ring-pad of the smaller song birds; all birds, however, are surpassed in thickness of ring-pad by the Swallow and the Sailor-bird.

In stronger development of the ring-pad, the nucleæ are always striated near the lens capsule.

Passing over the very insufficient statements of Ritter, I come to speak with Rabl's words, upon the appearance of the sections of the equator which remind one of the discovery made in the reptile:

"One sees that the filaments of the ring-pads turn from place to place with their thickened club-shaped ends or turn from each other, so that there develop very characteristic formations, which give the impression of indentations and which are repeated at regular distances around the whole ring-pad. The number of these indentations corresponds to the number of ciliary processes and these facts make obvious the presumption that the indentations owe their existence to the relation of the ciliary processes to the ring-pad. The same structure is met in the lens of most birds, only these are not shown everywhere with the same sharpness, I can recognize in these occurrences no direct workings of the pressure of the ciliary processes, but only adjustments of this pressure. The ring-pad receives through it that structure which is suitable to continue the pressure of the ciliary processes into the anterior.

The club-shaped enlargements of the extremities, as well as the spindle-shaped enlargements of the ring-pad filaments, which lie near the end, are especially large in diurnal birds of prey. While in these birds the spindle-shaped enlargements begin in the second fifth of the filament's length, in the Crows and Woodcracker, they appear only in the last third in great numbers. So there arise many differences, of which those in the work of Rabl must be especially pointed out."

Here would be the place to consider the epithelial margin of the

lens in Sauropsidia, where the ring-pad passes into the mass of lens fibres. Both in reptiles and birds the epithelial cells, or more often here the ring-pad cells, are arranged close in front of the epithelial margin in meridional rows.

The cavum lenticuli. Until now it has not been customary to speak of a cavum lenticuli in the full-grown lens, and in fact the cavity of the lens anlage, which is almost recognized in studies of the embryo, is reduced to nothing. As traces of this previous cavum lenticuli there are still to be found: first, the marginal surface between the lens epithelium and the lens fibre mass; second, the marginal surface or surfaces, where the single lens fibres turn their distal ends towards each other and so form the outer visible commissures on the distal pole—(while similar formations on the proximal pole comes under other points of view); third, perhaps some of the spaces between the lens fibres are derivatives of the cavum lenticuli.

Only the first of these three places is of great importance, in that in it a cavum lenticuli may persist in a fully developed eye. Where in Amphibians small cavities are visible, these might be traced to artefacts (post-mortem gaping-open), it is otherwise in Sauropsidia.

If we found an indication in reptiles that the ring-pad cells at their free end form drops of secretion, this forces us to the presumption that in them a space filled with secretion is present continuously between ring-pad and the fibre mass of the lens, and in birds, indeed, there can be shown such a cavity between the ring-pad and the fibrous mass of the lens; to be more exact, between the ring-pad and the cavum lenticuli. (However, the cavity between the cavum lenticuli and the lens may be an artifact.) Also, this cavity in the eye shows itself to be filled with a secretion which appears nuclear in slides.

Its presence might be important physiologically, as I have said in other places, for the completion of the lens accommodation in bird's eyes.

THE VITREOUS BODY OF VERTEBRATES.

According to O. Zietzschmann this jelly-like structure fills the space between the iris and the ciliary body. It is of spherical form except where at its anterior pole a concavity *(fossa patellaris s. hyaloidea)* exists, which corresponds to the convex border of the lens that fits into it. The larger part of the remaining superficies is applied to the *membrana limitans interna* of the retina. Only at the lenticular aspect of the orbiculus is the vitreous unattached to the inner aspect of the eyeball. In the posterior chamber [of Mammals] it comes in relation with the zonula of Zinn and the interzonular space. According to

Salzmann this whole space is filled with fibrillæ that stretch across from the pars ciliaris retinæ.

The vitreous mass contains 98 per cent water—the so-called *vitreous humor*—which slowly runs away on cutting into the vitreous body, leaving a more solid structure that is to some extent resisting on pressure. On closer examination the vitreous is found not to be a homogeneous body, but is irregularly crossed and recrossed by very fine fibrillæ that, according to Salzmann (*Zentralb. f. Physiologie,* 1900, p. 797), resembles a loosely arranged ball of cotton.

One may distinguish in the *corpus vitreum* a superficial layer—*hyaloid membrane*—of delicate fibres that encloses the whole structure and a still weaker and more delicate strand—the *nuclear portion.* Neither of these histological elements is sharply defined, their fibres intermingling with one another in all directions. They bear about the same relation to each other that the crust does to the softer parts of a loaf of bread.

At the surface of the vitreous body the fibres form a lamella and run in an equatorial direction. Ebner (Kollicker's *Handbuch der Gewebelehre des Menschen,* Vol. 3, 1902) believes that this condition is to be found only in the neighborhood of the *ora serrata,* where with the zonula of Zinn—in those animals in which it is present—it forms the hyaloid membrane of many authors. It has been noticed that a true hyaloid membrane is often absent towards the corneal aspect of the vitreous.

The vitreous fibres are especially in evidence and their connection with neighboring structures is particularly marked at the periphery of the central hyaloid canal, i. e., at the posterior lens pole and optic nerve.

In gross dissections of many birds' eyes, including the Sparrow, a fibrillar connection between the apex of the pecten and the vitreous mass was especially noticeable.

The vitreous appears to be chiefly the supporting mass of the retina and its superficial layer forms the limiting membrane of that coat, which is carried beyond the retina into and past the ora serrata. It acts, as Franz says, as a well-developed basal membrane for the retina, showing in birds a vestigium of the vitreous cleft and having attachments to the pectinate body. No deep cellular elements have been found in the vitreous body. Iwanoff (Graefe-Saemisch *Handbuch der ges. Augenheilk.,* Vol. 1, 1874, p. 265) found three kinds of cells in superficial areas—round, stellate and spindle-shaped. Virchow also discovered compressed cells with one or more nuclei, which he did not regard as "wandering" elements.

Kalt believes that the cellular elements of the vitreous consist of migrant and fixed cells.

Fishes exhibit a typical collection of connective tissue cells at the periphery of the vitreous, and these are seen in Amphibia and Reptiles. The vitreous blood-vessels constitute, with those of the retina and those that ramify about the lens in the embryos of Mammals, a separate system, which Virchow (*Bericht der Oph. Gesellschaft,* 1885) denominates the intraocular vascular system; Kalt (*Encyclopédie Française d'Ophtalm.,* III, p. 846), speaking of the embryonic blood-vessel supply that enters the fetal globe through the choroid fissure, says that from this source is derived (1) the superficial vessels that nourish the retina in Mammals, as well as the hyaloid of Amphibians, Reptiles and of those Fishes without a falciform process; (2) the deep vessels found in the pecten of Birds and its homologues, including the falciform process of Fishes. Beauregard (*Annales des Sciences Naturelles,* 1876) pointed out that this latter group of deep vessels, found in animals without a superficial blood supply, nourishes the vitreous and the retina.

The *vitreous cavity is very deep* in Fishes—3 to 4 mm. in the Perch, Ray and Shark. It is 5 mm. in the Crocodile and 1 mm. in the Frog. In cold-blooded animals it varies with the length of the antero-posterior diameter. For example, in the Eagle it is 16 mm., 17 mm. in the Ox, 19 in the Horse, etc.

Over the whole extent of the retina the vitreous body adheres to the hyaloidal membrane; it also exhibits several attachments to the ciliary body and to the optic papilla. The falciform process in the Fish, and the pecten of Birds may be compared with the last insertion; in both cases there is a continuity of tissue between the vitreous and the conjunctival or epithelial wall to which it adheres, and it is easy to demonstrate this adhesion by examining a fresh vitreous body.

Lizards and Chelonians lack, just as Birds, both hyaloid and retinal vessels. Snakes have at the surface of the vitreous body a rich network of vessels and their cone is reduced to a kind of papillary pad. In the Couleuvre à collier the hyaloid artery is supplied by the ciliary vessels.

In the amphibian, Urodeles, there are no true intraocular vessels while the Anura have about the vitreous a well-formed vascular network visible by means of the ophthalmoscope, when in consequence of the considerable magnification of the image, it is easy to distinguish the movement of the blood corpuscles. The hyaloid artery, dividing into two branches, forms an anterior vascular circle near the ora serrata.

In Fishes, hyaloid vessels are generally found, being absent in all the cartilaginous orders, although the Lamprey has a small hyaloid bud in its vitreous. They are also wanting in the Salmon, the Cod, and the Perch.

The entrance and exit of the hyaloid vessels of certain Fishes is interesting. In the bony Ganoids it enters in front and below near the ora serrata; in the Eel across the optic disc; finally, in quite a number of Fishes, the artery enters separately by way of the papilla and the exit of the vein is at the ora serrata.

On the ventral side of the choroid at the opening of the choroid gland in Cyprins there is a well-developed plexus of hyaloid vessels which Kalt calls the *lenticular body.*

The hyaloid plexus of reptiles, amphibians, and fish. We do not need to occupy ourselves here with birds which do not possess vessels of the retina or of the hyaloid. In them the comb probably has the function of a secretive apparatus of vitreous humor. The vessels which constitute it are anastomosed with the system of ciliary vessels. The hyaloidal plexus is limited in the birds to the organ of the comb; in the embryo there is no vascular capsule of the crystalline lens.

PECTEN, MARSUPIUM OR COMB OF BIRDS. PECTEN OR CONE OF REPTILES. FALCIFORM PROCESS OF FISHES.

The pecten in Birds. By means of the ophthalmoscope and direct illumination there is seen, below and externally, in the fundus of Birds a black mass of variable form. When the free edge of this organ is illuminated one notices a longitudinal strip with undulating edges. If one throws the light upon the base of this object—the *pecten* or *comb* —the papilla looks like a sparkling white area whose margins are edged with black, the center being occupied by the irregular, black mass.

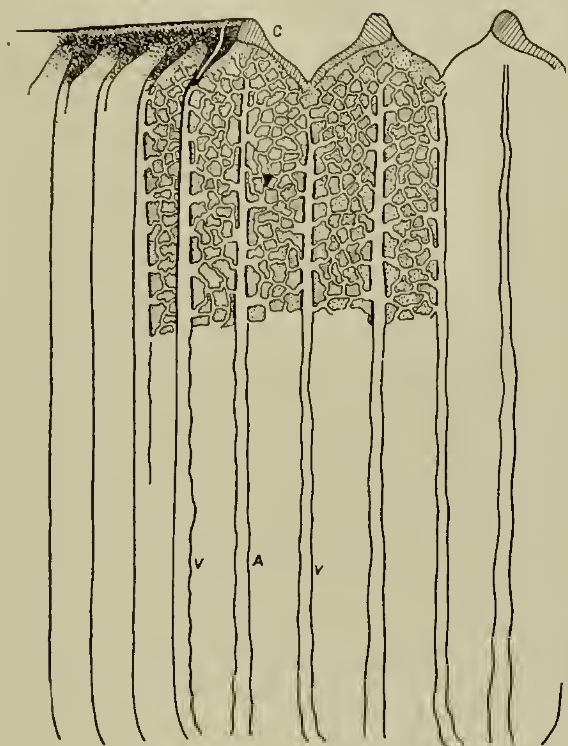
The pectinate image seems to be displaced by abrupt movements in the vitreous mass, disturbances due to contractions of the ocular muscles, external and internal.

According to Ziem, the pecten is an erectile organ whose volume varies within rather wide limits. In a state of tension, it partially covers the crystalline lens and hides the pupillary orifice. That is, in addition to its function as a nutritive organ, it plays the rôle of an accessory diaphragm regulating the entrance of luminous rays into the depth of the eye.

As Kalt says, the pecten is a membranous organ covered by a black pigment attached to the optic nerve and projecting a variable distance

into the vitreous body. This organ, studied and described for the first time by Perrault, in 1876, received later the name comb *(peigne)*. The German authors still call it the "fan" *(Fächer)*. Except in the Ostrich, where it has the form a cone inserted in the optic nerve and divided into two parts by a sort of white partition, the pecten represents a triangular or rectangular pigmented lamina, whose plane is directed down and outward.

Generally it does not extend to the intercalary segment of the sclerotic, and it is only exceptionally, as in the Goose, the Swan, the



Enlarged Drawing from a Dissection of the Pecten to Show the Arrangement of the Arteries (A) and Veins (V) and their Connecting Capillaries. (Wood and Slonaker.)

The union of the folds at the free margin of the pecten has been cut at C to enable the folds to be spread out flat.

Stork, etc., that it reaches the crystalline lens. The comb is made up of a lamina folded upon itself and resembling, in a transverse section, the zig-zag aspect of a collar. The number of plications varies from 5 to 30, averaging 16, as in birds of prey and Gallinaceæ. The writer and Slonaker counted 18 folds in the English Sparrow. The term "comb" is not exact since there are no separate teeth; perhaps "fan" would better describe the appearance of this organ.

Among the Owls, the length of the comb is 5 mm. at the base; and its height 4 mm. In the Stork, the base is 13 mm. long and it is 7 mm. high.

Kalt believes the pecten to be essentially a vascular organ. It is composed of a network of capillary vessels of unequal dimensions spread out in two or three superimposed planes, whose mesh may vary in form and dimensions. In the Goose the vessels are nearly all parallel, the anastomoses are rather rare and the meshes acquire a great length. The thin connective tissue which serves as a support, contains free pigment. The entire organ is enclosed in an envelope of endothelium.

Kalt further thinks that the pectinate blood-supply is derived from the external branch of the internal carotid, which immediately after leaving the temporal, forms a large *plexus*. The vessels which leave the plexus cross the sclerotic and re-unite in a single trunk, which corresponds to the central artery of the retina of the mammifers. This trunk extends to the base of the comb and detaches from it several ascending vessels, which penetrate the latter and form a large capillary plexus. The venous blood is returned by a large choroidal vein which perforates the sclerotic a short distance towards the middle of the comb. Note that it makes at the level of the ocular groove several variable anastomoses with the plexus of posterior ciliary arteries.

According to Beauregard the pecten is allied to the choroid. It appears after the fourth day in the embryo of the hen.

The function of the comb has from time to time been variously interpreted. It has been considered particularly as an erectile organ capable of displacing the crystalline lens and of taking part in the accommodation of the eye. Beauregard, using the ophthalmoscope, found displacements and rapid vibrations synchronous with the movements of the nictitating membrane. But he noticed, above all, that the comb is placed so as to intercept the rays coming from the front and from above; that is to say, those rays that reach the two eyes simultaneously. In catching them, the pecten is supposed to suppress momentarily, in this way, binocular vision, a condition which is necessary for the more perfect use of the monocular vision.

No doubt the pecten also serves as a screen to protect the retina against the rays of the sun. Observation of the attitude of the Hen's head, when exposed to the sun, is favorable to this supposition, as, also, the slight development of this organ among nocturnal birds.

Finally, one hypothesis which seems plausible, attributes to the comb the rôle of an organ of nutrition for the vitreous body and makes of it an appendage of the ciliary body. It has also been suggested that it is an organ of excretion, charged with maintaining the intraocular tension.

Franz (*Sehorgan*) does not believe that the finer structure of the bird's pecten has, as yet, been cleared up. The organ, he says, is present in all birds; even in the Apteryx, in which its presence had long been denied on account of insufficient preparations, Lindsay Johnson, however, found it. The structural arrangement, as in Struthio, shows it to be different from other birds, where it springs as a sort of wrinkled leaf from the papilla and has an enlargement, which he terms the "bridge," which runs along the entire margin of the pecten. The folds are welded together by this bridge, so that they can only be smoothed out by cutting away the latter.

The *histological structure of the Bird's pecten* touched upon by Mihalkowics and Denissenko has been more recently described in the *Dissertations* of Parrault and Bernd, where it was shown that the pecten is not primarily of mesodermal origin and an appendix of the choroid, as was formerly held (by Kessler, for instance), but is primarily a derivative of the retina or of the optic nerve; in short, an offshoot of the central nervous system and, consequently, of the ectoderm.

Franz maintains that the pecten is a sense organ, assisting in the regulation of the intraocular pressure and the act of accommodation.

On the upper surface of the pecten, that is on the "bridge," Franz found filaments that ended there in club-shaped bodies, structurally between pigmented nuclei and cell nuclei, and he believes we may look upon the pecten primarily as a glia-structure, an opinion also held by Blockmann and v. Husen.

Still, Franz will not say, nor does Blockmann, that there is to be found in the pecten any convincing evidence of the presence of true nerve filaments.

Franz and Hushke point out that the pecten is all the more developed, the more the bird makes use of monocular, and less of binocular vision, which has been pointed out by Hushke. The pecten of song-birds is large and rich in wave-like folds, and in these animals the fovea nasalis, the area of distinct monocular vision, is the only one they possess. The much faster flying Swallow, with better accommodation, has a more poorly developed pecten and in its retina are found in addition to the fovea of monocular vision, the round fovea of temporalis binocular vision. The owls, also, with their small pecten have binocular fixation. Franz thinks that these facts show that the pecten has a sensory function and perceives changes in intraocular pressure and in accommodative sensations.

The statement by Abelsdorff and Wessely (1909), that the pecten

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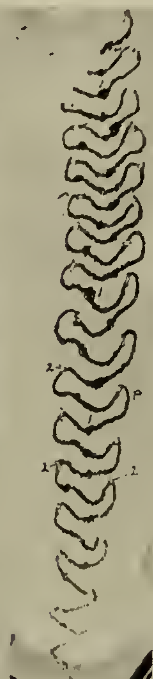

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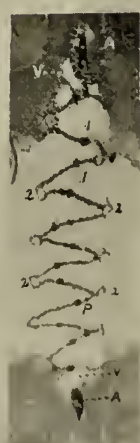

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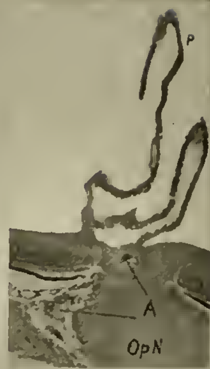

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Microphotographs of the Sections Through the Pecten at its Base of the Pecten. (Wood and Slonaker.)

1, Arteries; 2, veins of the pecten; *A*, artery at the base of the pecten, just before and after entering the eye; *Op n*, optic nerve; *C*, cartilage of the sclerotic much thickened at the nerve entrance; *P*, folds of the pecten; *S*, sclerotic; *V*, vein at the base of the pecten.

Fig. 171.—Section almost parallel to the extent of the pecten and perpendicular to the retina, showing the optic nerve entrance and a portion of the crest of the pecten. A portion of the basilar vein is seen at *v*. x 38.

Fig. 172.—Section almost parallel to the extent of the pecten through the lateral portion of the pecten folds some distance from where the optic nerve first pierces the sclerotic. x 38.

Fig. 173.—Section more distant from the first or primary optic nerve entrance, showing how the distal portion of the nerve lies under or within the sclerotic. x 38.

Fig. 174.—Section at right angles to the folds of the pecten, showing the folded arrangement and the location of the arteries (1) and veins (2). x 38.

Fig. 175.—Section at right angles to the folds of the pecten near its base showing the basilar artery *A-A*, and basilar vein *V-V*, also the arteries (1) and veins (2) of the folds of the pecten. x 38.

Figs. 176, 177, 178.—Section at right angles to the optic nerve almost parallel to the folds of the pecten, showing the basilar artery A, and vein V, cut across.

Fig. 177.—This shows where the artery enters from the outside of the eye. x 38.

receives single nerve filaments does not seem to be justified on careful examination of microscopic slides.

Both in Birds and Reptiles there is a close connection between the pecten and the vitreous, in other words between that organ and the margins of the hyaloid canal or slit in which it is, as it were, inserted.

According to Abelsdorff and Wessely, the pecten is separated from the vitreous by a homogeneous covering only, which these authors regard as a modification or continuation of the *membrana hyaloidea*. This is said to stretch from its tip to the base, and in the developed pecten is found to unite closely the bridge of the pecten and the vitreous.

In the completely developed reptilian cone the topography of the vessels has not been accurately worked out. In the embryonic stages of the Lizard, Kessler found an entering artery on the vertical side of the pecten, which apparently makes its way out of the cone and into the vitreous, to the *pars ciliaris retinæ,* where it makes its exit from the globe.

Franz does not feel certain about the vascular supply of the pecten of the bird. He believes, however, that the blood-vessel which runs along the base of the pecten gives off branches to the folds thence many twigs to them and, to a less extent to the pectinate bridge. The main vessel is to be regarded as the artery (afferent vessel) of the pecten.

Thus, Franz concludes, we recognize in the pecten an organ which is primarily a vessel-bearing glia-growth, principally characteristic of the Sauropsida, and which attains considerable size and differentiation in birds.

Moreover, we find similar glia-growths emanating from the papilla in many Mammals and which are the same character as these organs in Reptiles. In the eye of the Amphibians and Fishes there are no corresponding glia-growths, but at the most only weak glia-like remains.

After many dissections and much consideration of the finer anatomy of the organ Slonaker and the writer do not regard the pecten as anything more than a series of bloodvessels with a deeply pigmented framework of glia fibres and cells. So far we have been unable to find in numerous serial sections of the Sparrow's pecten (or in that of any other bird) definite ciliated structures, sensory buds, or any other appearance that would justify a belief other than that this organ, deeply pigmented to absorb the light rays, has any other function but that of a carrier of nutritive pabulum, chiefly to the vitreous and anterior layers of the retina. It may change its position, actual or

relative, during accommodation, but it has no other connection with the accommodative act. The covering of all its fan-like folds is continuous and identical with the hyaloid membrane or membrana limitans of the retina. We did not find in the Sparrow any anastomoses between the vessels of the pecten and the other ocular structures. The branch of the ophthalmic artery that enters the eyeball close to the optic nerve sheath (to penetrate the latter at the plane of the sclerotic coat) is the only afferent vessel-supply of the pecten that we were able to demonstrate, either by gross dissection or in serial microscopic sections of this region.

In the same way there appeared to be only one efferent vein which may, however, have received other venules before its exit from the globe, several millimeters distant. These two latter observations are, however, based on an incomplete dissection of the parts and may be modified later.

In this judgment, if we read him aright, Treacher Collins, to some extent, concurs. In his Erasmus Wilson Lectures on the Anatomy and Pathology of the Eye he remarks that "in other animals than Mammals and in the human fetal eye there are other sources for nutrient supply to the intraocular structures in place of or in addition to the ciliary body." He adds that the pigmented, plicated structure of the bird's pecten "closely resembles the choroidal coat * * * having, however, a rather finer capillary plexus. Birds, therefore, not only possess well-formed ciliary processes but also a special vascular arrangement in the vitreous chamber."

According to O. Zietzschmann, also, the pecten is covered by a delicate membrane which is continuous with the inner limiting membrane of the retina. The bloodvessels, according to him, belong to the ciliary system and are branches of those supplied to the optic nerve. Leber (Graefe-Saemisch *Handbuch der ges. Augenheilk.* 2nd Edition, Vol. 2, part 2, 1903) believes the pectinate artery to be the homologue of the hyaloid artery, but which in the bird does not extend out into the vitreous. Numerous branches extend from this basilar artery into the pecten where they break up into capillaries.

Finally, it may be added, that there are no bloodvessels in the Birds' retina and the vessels of the pecten do not, consequently, arise from a central artery of the optic nerve as in Mammals since that, too, is wanting.

The areas of the retina in Birds. In birds we find fundi of greater variety and foveæ in greater number than in reptiles, in addition to other interesting regional differences, of which must not be forgotten the variously colored oil-droplets.

According to Chievitz (1891) and Slonaker, there is at least one round macular region with a fovea in practically all birds.

The fovea, or area of monocular vision, is in most Birds situated somewhat centrally and slightly temporally.

In diurnal Birds of Prey, besides the central fovea (fovea nasalis) there is a lateral one present, which serves for binocular vision.

In the Owls and members of a few other orders, which resemble the former in having their eyes placed in front, there is only a lateral fovea, which with that of the fellow eye enables the animals to obtain binocular vision.

Besides this central area (with fovea) there is often, in Birds, a streak-like or band-like arrangement of retinal tissue that is generally found in the horizontal meridian. It is mostly seen in those birds that seek their food upon the ground, e. g., Motocilla, Saxicolla, Numensicis, Recurvirostra, Totanius, Tringa, Geese, Larus, Simosa, Squatarola, Strepsilus, Vanellus, and Aquatic birds.

In Cypselas (Sailor-bird), Hirundo (Swallow), Sterna (Tern or Sea-swallow) there are found all three foveæ. Slonaker has given a full account of the foveæ of the last-named.

The retina manifests the greatest foveal development in swift-flying birds.

The *depth of the fovea* may be regarded as a measure of the sharpness of vision. We find the round fovea especially "deep" in Song-birds and Birds of Prey; "medium" to "weak" in the remainder of the species, except that it is "shallow" in the domestic Pigeon, and lacking altogether in the domestic Hen.

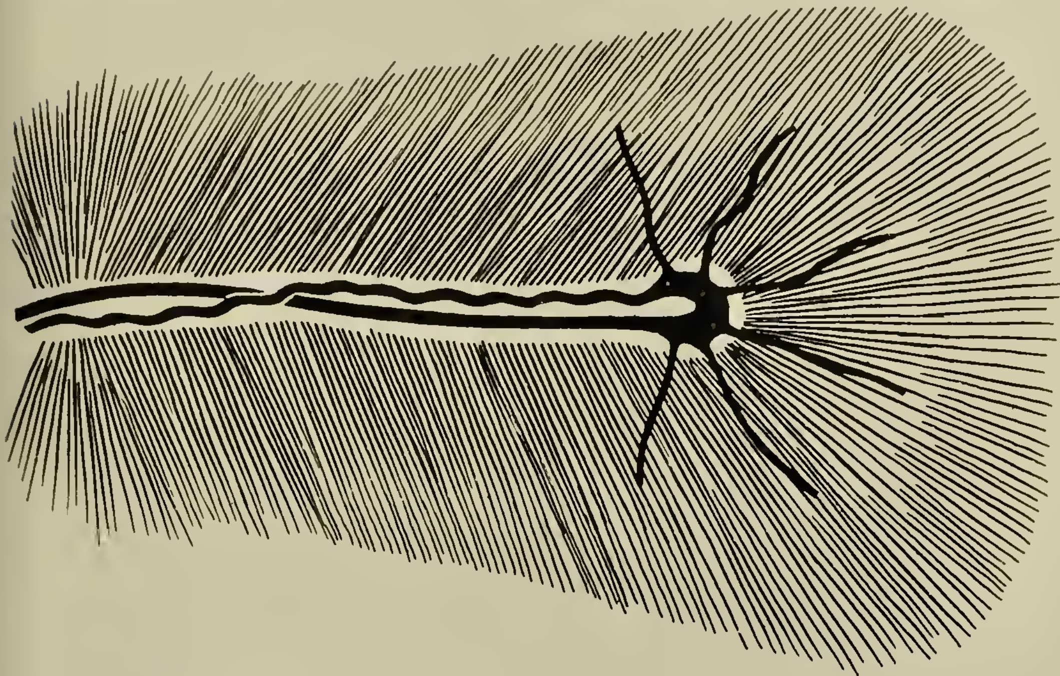
Krause is probably right in believing that domestication brings about the disappearance of the fovea. In the domestic Pigeon its depth varies, according to Slonaker.

Both foveæ of diurnal Birds of Prey are structurally much alike, in that they have in them only cones, and only those with yellow droplets.

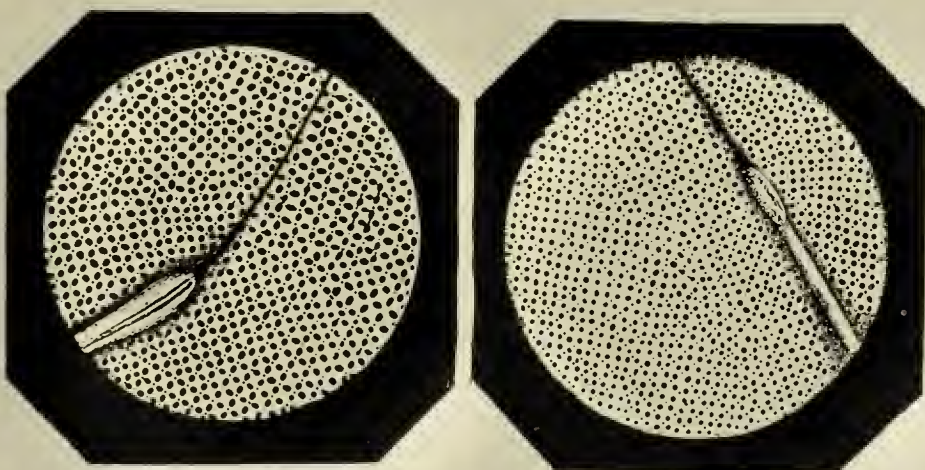
OPHTHALMOSCOPIC APPEARANCES OF THE FUNDI IN VERTEBRATES.

Beauregard (*Annales des Sc. Nat. 6^{me} Série, Zool.*) first reported definite observations on this subject and after him Beer (*Pflüger's Archiv*, 1894). Franz, Cuignet, Berlin and other observers have also published scattered notes on this matter. The most complete study of the fundus appearances in Mammals has, however, been made by Lindsay Johnson (*Contributions to the Comparative Anatomy of the Vertebrates, chiefly based on Ophthalmoscopic Examination*, London, 1901) to whom we owe much for valuable information on the subject.

The great variety and beautiful pictures obtained by views of animal backgrounds with the mirror and their value in classification can be appreciated only by those who have examined a number of varieties



Ophthalmoscopic View of the Fundus of the Fish—*Gadus merlangus.* (Beauregard.)
The processus falciformis (black) runs the whole length of the (white) optic nerve, at the periphery of which is seen six branches of the hyaloid artery.



Ophthalmoscopic Appearances of a Part of the Fundi of (left) the right Eye in Scorpaena scrofa. The Optic Nerve Entrance in its relation to the processus falciformia is shown, as well as the peculiar mosaic arrangement of the background. The cut on the right is a somewhat similar view of the left fundus of Blennius ocellaris. (Franz.)

of animals with the ophthalmoscope. In *wild varieties* the colored and often brilliant picture of the background practically never varies, and it is just as possible for the expert to determine the family, and

sometimes the order, of a Reptile, Bird, Fish, or Mammal by examining its fundus oculi as it is for the artist to distinguish at a glance a Rembrandt from a Raphael, a Rubens from a Franz Hals, or a Corot from a Turner. In domestic animals, Man, for example, the variations in the fundus appearances of individuals are marked, and the same is largely true of our house animals, whose habits (and eyes) undergo a variety of changes corresponding with their changed and changing environment. In Vol. II, page 979, of this *Encyclopedia,* under

Fundus of the Indian Cobra—*Maia tripudians.* Left Eye. Erect Image. (Drawn by A. W. Head.)

Birds, Eyes of, several fundus views in their natural colors are to be seen.

The fundi of Fishes may be examined out of water if they are kept alive by a current of water supplied to the mouth and gills. The examination is made with either the direct or indirect image; in the latter case a view of the "mosaic" of the cones is obtained.

Depending on whether the falciform fold is more or less developed, the appearance of the papilla in Fishes differs. In those Fishes where it is not visible, as in the Carp, the papilla appears more or less round and from its center emerge vessels, that branch in all directions. In

the Perch one sees in the lower part of the fundus a long, white band leaving the optic entrance and directed downwards and forwards. The center of this band is pigmented. In the Rock-Fish numerous vessels leave the pigmented optic nerve entrance, to run through the hyaloid body.

Mammalia. According to Johnson, in animals with no tapetum, it is the pigment of the choroid that gives color to the fundus of the eye. Where there exists a cellular tapetum, as in Carnivora, the coloration

Fundus of the Horned Toad—*Ceratophrys cornata,* South America. Left Eye. Erect Image. (Drawn by A. W. Head.)

is furnished by the pigmented epithelium of the retina. In hoofed animals, the fibrous tapetum, or the coloration of the retinal pigment, furnishes the ocular fundus with its special coloration. The author distinguishes three varieties of fundus coloring:

1st. The background *red,* but less clouded by brown or grey. This form is found in almost all the Primates, some Insectivora, some Carnivora, the Camel, the Hog, and the Rhinoceros, among hoofed animals; in almost all the Rodents, toothless animals and Marsupials.

2nd. The fundus *yellow,* seen in Cheiroptera, some Felidæ, the Tapir and the Elephant; and Pteromys.

3rd. The fundus *green*, in the Carnivora and the Selenodontes, with the exception of the Sheep and the Goat.

Opaque nerve fibres at the periphery of the papilla are found among Rodents and Marsupials.

The Felidæ, many of the Carnivora, and some Rodents exhibit a *physiological cup.*

The abnormal persistent hyaloid artery of Man is a normal vessel in all Ruminants and many Rodents. Among the latter, also, one frequently finds some rudiments of the pecten in the vicinity of the papilla. Many Mammals also have an appearance analogous to coloboma of the papilla. In the fundi of Galagos and Lories are found normal pigmented formations resembling human *retinitis pigmentosa.*

One sees distinctly the choroidal vessels in the Gibbon and the Kangaroo. A dotted pigmentation appears in certain Felidæ and in the Lemurs.

The optic papilla is generally round; but it is club-shaped in the Wolf, the Fox and Jackal; oval in the Horse; round in the Llama, the Goat, the Tapir and the Rhinoceros; in the form of an elongated band in the Squirrel. Its color is rose in Man, Monkeys and the Artiodactyls; it appears black or green in the Galagos and Lories; quite white in Bats, the Lemurs, Rodents, Edentates and Marsupials; red in Equidæ. Carnivora have grey, brown, red or white discs.

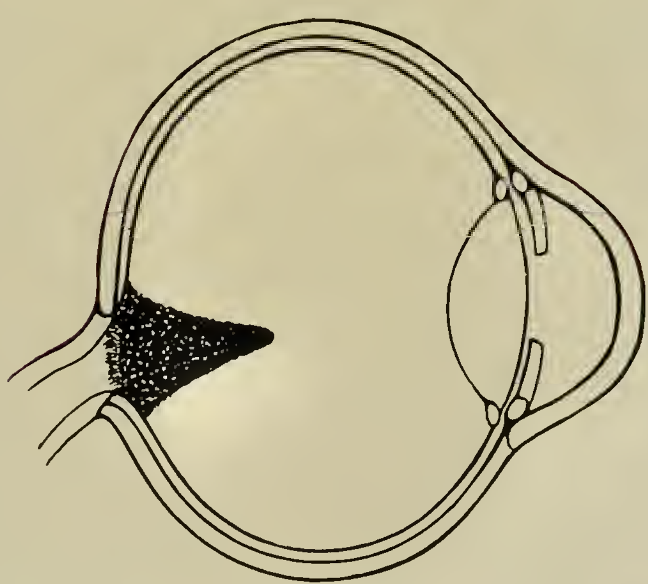
Distribution of vessels of the fundus of domestic animals. The most completely vascularized retina is found in Man, then come the Carnivora, Ruminants, the Pig and the Rat. A small portion only of the retina is provided with vessels in the Horse and Rabbit. In the latter they extend in a horizontal direction.

By reason of the situation of the papilla in the lower hemisphere the ascending vessels are particularly developed in Ruminants and the Pig, while in the Horse and the Rabbit the principal vessels have the same size. The venous and arterial vessels communicate through an intermediate capillary plexus; but there are examples of some direct anastomoses—well seen in the Sheep.

In the fundus of many Carnivores, especially of the Canidæ, the optic disc is situated near the plane of the vertical meridian of the eyeball, 2 mm. below the horizontal meridian. It is fan-like or of oval, or triangular shape; its surface is flat; its coloration is pale yellow, white, or bluish. From the center, sometimes also from the margin, emerge three or four arteries accompanied by their veins and some small arterial and venous branches.

The venous trunks are often reunited upon the papilla by anastomoses. This gives ordinarily the appearance of a ring opened on

Fundus of the Turkish Gecko—*Hermidactylus turcicus.* Left Eye. Erect Image. (Drawn by A. W. Head.)



Pecten of the Turkish Gecko—*Hermidactylus turcicus.* (Drawn by A. W. Head.)

the ventral-oral side. The arteries penetrate the optic nerve 1 or 2 mm. back of the sclerotic. The circulatory layer of the retina is supplied partly by the posterior ciliary vessels. While in the Ruminants, the Pig, etc., there are only two or three short posterior ciliary arteries; these are, on the contrary, very numerous in the Dog. They penetrate the sclera at the periphery of the optic nerve, and give off, towards the papilla, a branch which anastomoses with the central vessel and finally loses itself in the retina.

Lindsay Johnson *(loco cit.)* gives the following description of the accompanying figures, illustrating the ophthalmoscopic findings in various species of Mammalia.

Fundus of the Common Hedgehog—*Erinaceus europeus.*
(After Lindsay Johnson.)

Fundus oculi of the Common Hedgehog—*Erinaceus europaeus.* The background is uniformly light-grey. The disc is small, circular, and pink. From this two sets of vessels proceed, viz., a peripheral set, which emerge from its edge in the form of five branches of minute capillary threads, and a central set, consisting of five large retinal vessels, which radiate to the periphery like the arms of a Starfish. There are no choroidal vessels visible, nor can the arteries be in any way distinguished from the veins.

Fundus oculi of the Hog Deer—*Cervus porcinus.* The disc is remarkable apparently consisting of three separate discs fused together. From the center of each of these "discs" an arterial trunk proceeds, accompanied by its vein. The semi-opaque nerve fibres are very prominent and coarse, otherwise it resembles the fundus of the Ruminants.

Fundus oculi of the Bactrian Camel—*Camelus bactrianus.* The fundus is uniformly chocolate-red in color, the lower portion appearing paler, owing to the innumerable radiating nerve fibres. The disc is white, circular, and covered with a network of pigment. The main trunk ascends, intertwining with its vein, and gives off oblique and horizontal branches.

Fundus oculi of the African Elephant—*Elephas africanus.* The fundus is of a uniform pale straw-yellow color, and covered with an immense number of peculiar irregular or bent brownish rod-like

Fundus of the Hog-Deer—*Cervus porcinus.* (After Lindsay Johnson.)

patches. The disc is large, circular, and grey, like a grey atrophied disc in man. The retinal vessels are limited to six or seven minute ones, which spread a short way beyond the margin of the disc. There is no peripheral zone.

Fundus oculi of the Common Squirrel—*Sciurus vulgaris.* The disc is of an enormous size for so small an eye. This is, with few exceptions, the case in all the Squirrels. It is placed well above the axis of vision. The retinal vessels are bright scarlet, and remarkable for their size and number, and there is no distinction between arteries and veins.

Fundus oculi of the Canadian Beaver—*Castor canadensis* and of the Chinchilla—*Chinchilla lanigera.* The fundus in each of these

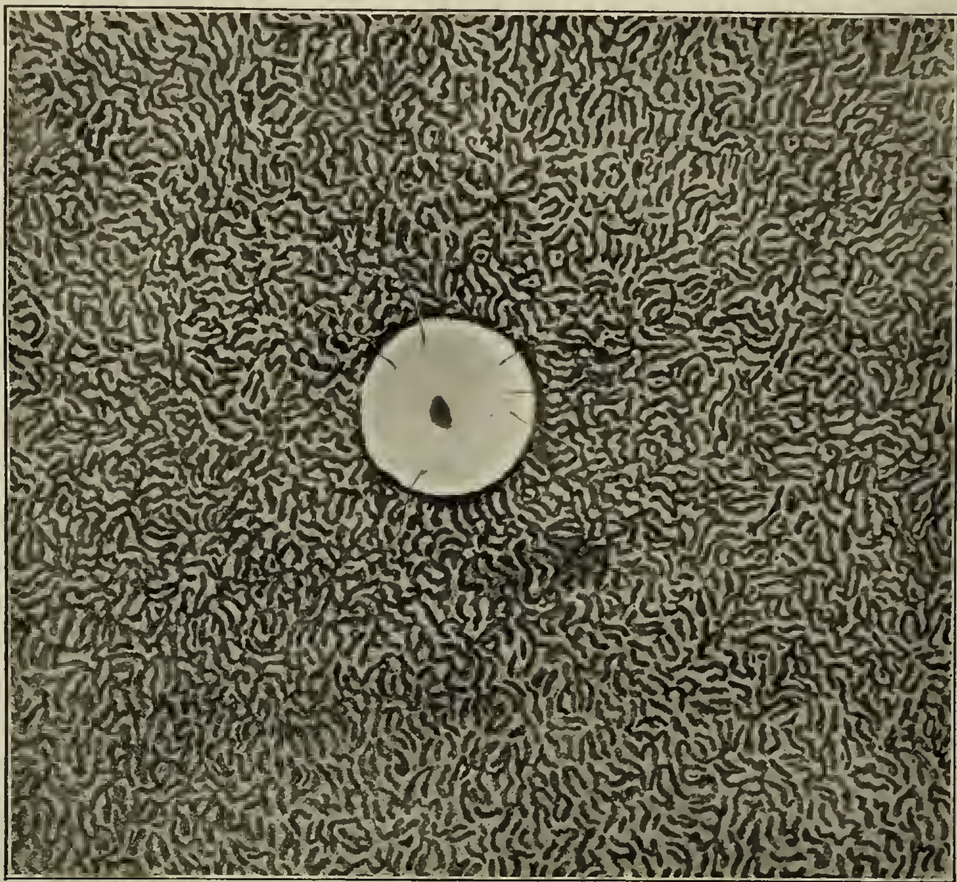
animals is almost identical, except that the former has a peculiar conical prominence projecting from the center of the disc.

Fundus oculi of the Brazilian Porcupine—*Sphingurus prehensilis.* The fundus is most primitive, as is the case in most animals which

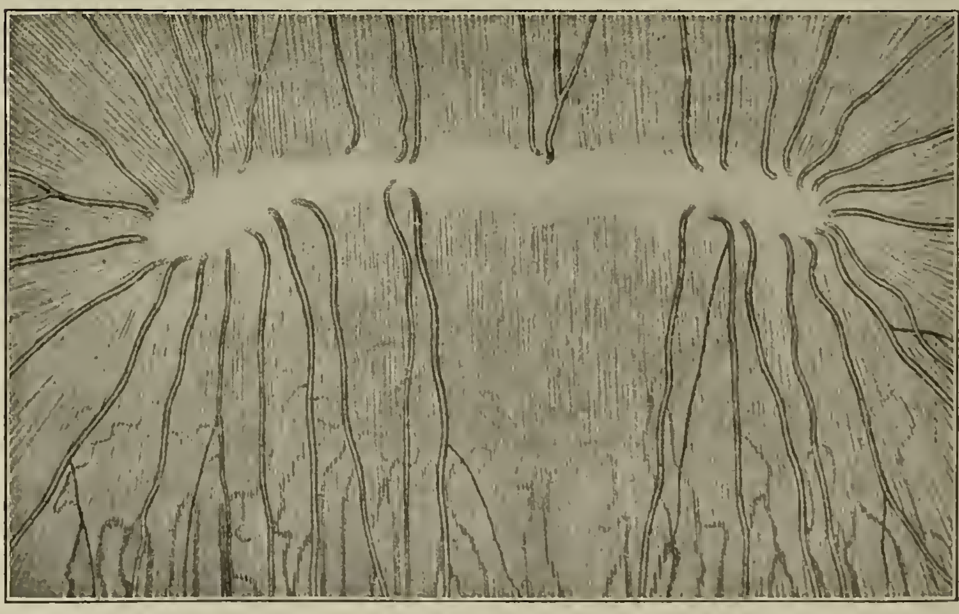
Fundus of the Bactrian Camel—*Camelus bactrianus.* (After Lindsay Johnson.)

are specially protected from injury by nature. No peripheral area, and no trace of retinal vessels, exist.

Fundus oculi of the Virginian Opossum—*Didelphys virginiana.* It is remarkable for possessing a golden central zone, which is sur-

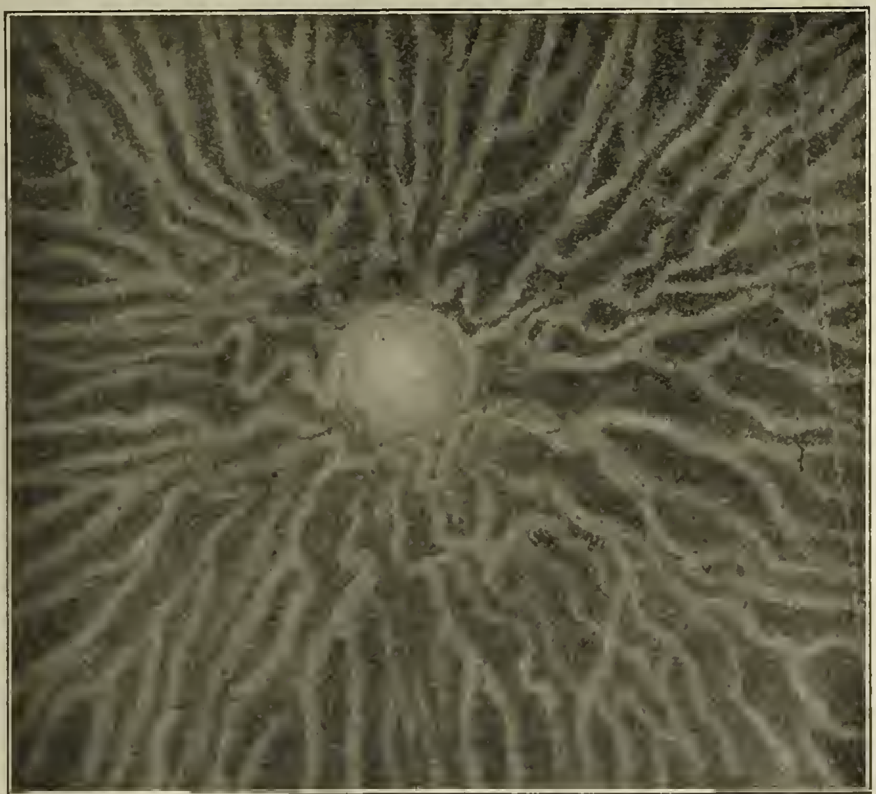


Fundus of the African Elephant—*Elephas africanus.* (After Lindsay Johnson.)



Fundus of the Common Squirrel—*Sciurus vulgaris.* (After Lindsay Johnson.)

Fundus of the Canadian Beaver—*Castor canadensis.* (After Lindsay Johnson.)



Fundus of the Brazilian Porcupine—*Sphingurus prehensilis.* (After Lindsay Johnson.)

rounded by a peripheral zone densely pigmented. It also possesses a grey disc and well-developed retinal vessels.

THE OPTIC NERVE OF VERTEBRATES.

In all vertebrates the optic nerve has the form of a cord, sometimes very short, as in Birds, and occasionally long as in Man, which extends from the optic foramen to the posterior segment of the eyeball, where its expansion forms the retina.

Fundus of the Virginian Opossum—*Didelphys virginiana.*
(After Lindsay Johnson.)

In Birds whose ocular movements displace the eyeball very little, the nerve is represented as a cord which is almost rectilinear; while in animals with mobile eyes, such as the large mammifers, the nerve is long, round and S-shaped, to follow the displacements of the posterior hemisphere without pulling or dragging. Its diameter greatly

Fundus of the Tigrine Frog—*Rana tigrina*. Left Eye. Erect Image.
(Drawn by A. W. Head.)

varies in vertebrates; it may reach 8 mm., as in the Whale. The rule is that it varies with the volume of the eyeball.

As Kalt (*Encyclopédia Française d'Ophtal.*, Vol. II) says the pia mater forms the neurilemma of the optic nerve. The multiple partitions which it sends into its substance, divide the nerve into bundles; the dissepiments anastomose with each other. It is the type well known among all Mammals. Birds exhibit one peculiarity; at the inner aspect of the nerve the pial partitions penetrate perpendicularly into the substance of the nerve and do not anastomose until they reach about half way into the thickness of the cord. Analogous perpendicular partitions, but very short, exist sometimes on the external side. The result is that the nerve has a foliated appearance, especially marked on the internal side.

The dura mater forms for the optic nerve a thick external sheath. It is continuous on the one hand with the sclerotic and, on the other, near the optical foramen, joins the orbital periosteum. The external layers of the dural sheath are mainly formed of longitudinal layers of connective fibres mingled with vessels, while in the internal layers the connective fasciculi have a circular direction. The external fibres are well developed in the large Mammalia, such as the Whale and the Elephant; also in the Sturgeon. In the Whale the thickness of the external sheath of the nerve attains almost that of the sclera, almost if not quite equal to the length of the antero-posterior axis of the eyeball. (See the illustration under Sclera.)

Between the internal and external layers of the dural sheath there is a space in the form of a slit, several millimeters in length, which in the Whale is prolonged into the interior of the scleral wall, where it is enlarged laterally. In its interior is a soft tissue composed of fat and vascular loops. The latter are composed of branches furnished by the posterior ciliary arteries that first branch and then reunite before penetrating the choroid. The lumen of these vessels is considerable, and their walls are destitute of muscular fibres. The purpose of this plexus is the diminution or slackening of the flow of blood before it enters into the eye. As a result there is, when necessary, a considerable reduction of intravascular pressure at this point. There is a certain analogy in this plexus of the Whale's eye with the choroid gland of Bony Fishes. Schwalbe also points out that in the Elephant there is a system of anastomoses of arterial vessels in the back of the globe which appears to have the same purpose.

The internal, circular layer of the dural sheath of the optic nerve is united to the pial covering, separable from it in Mammals and Birds. This sheath is, in fact, a prolongation of the cranial arachnoid.

Variations in the supporting elements of the optic nerve. As previously stated, in the higher Mammalia, including Man, the optic nerve is sub-divided by means of connective tissue bands which serve as a support for the vessels. In addition, the whole nerve mass is separated into isolated bundles by a pial membrane having a similar origin.

The sub-classes and orders of animals exhibit great differences in the distribution of these connective tissue partitions.

As a rule, as Deyl pointed out, the higher the animal in the vital

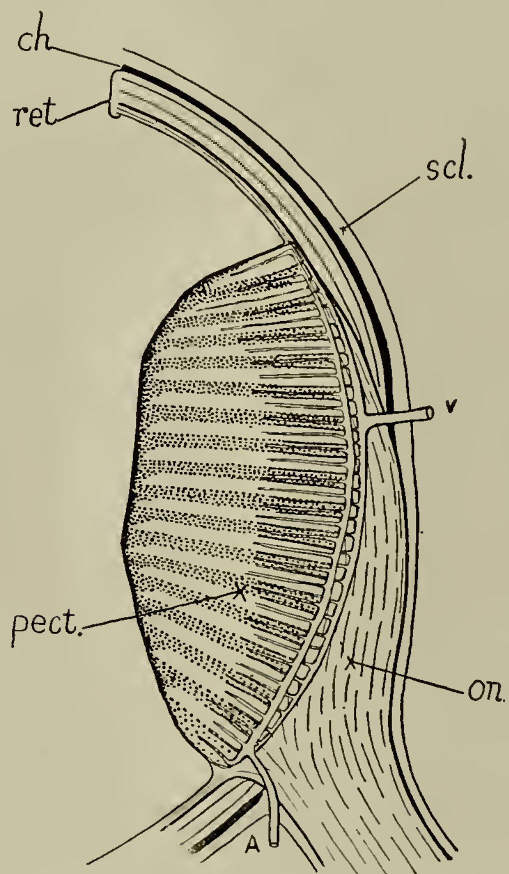


Diagram Showing the Relations of the Optic Nerve Entrance to the Pecten and the Basilar Artery and Vein in the Sparrow. (Wood and Slonaker.)

A, Artery to pecten, which sends a branch along each fold; *ch*, choroid; *on*, optic nerve; *pect*, pecten; *ret*, retina; *scl*, sclerotic; *v*, vein from pecten, which receives a branch from each angle of the folds.

scale, the greater the number of optic nerve partitions, and the more distinctly are the nerve pencils separated from each other. Assuming that there are about 1,000 nerve-bundles in the optic nerve of Man, there are no more than 300 in the Orang and other Monkeys.

On the other hand, the optic nerve tissues of Fishes furnish one of the exceptions to the rule formulated by Deyl.

The *optic nerve of invertebrates* has been exhaustively studied by

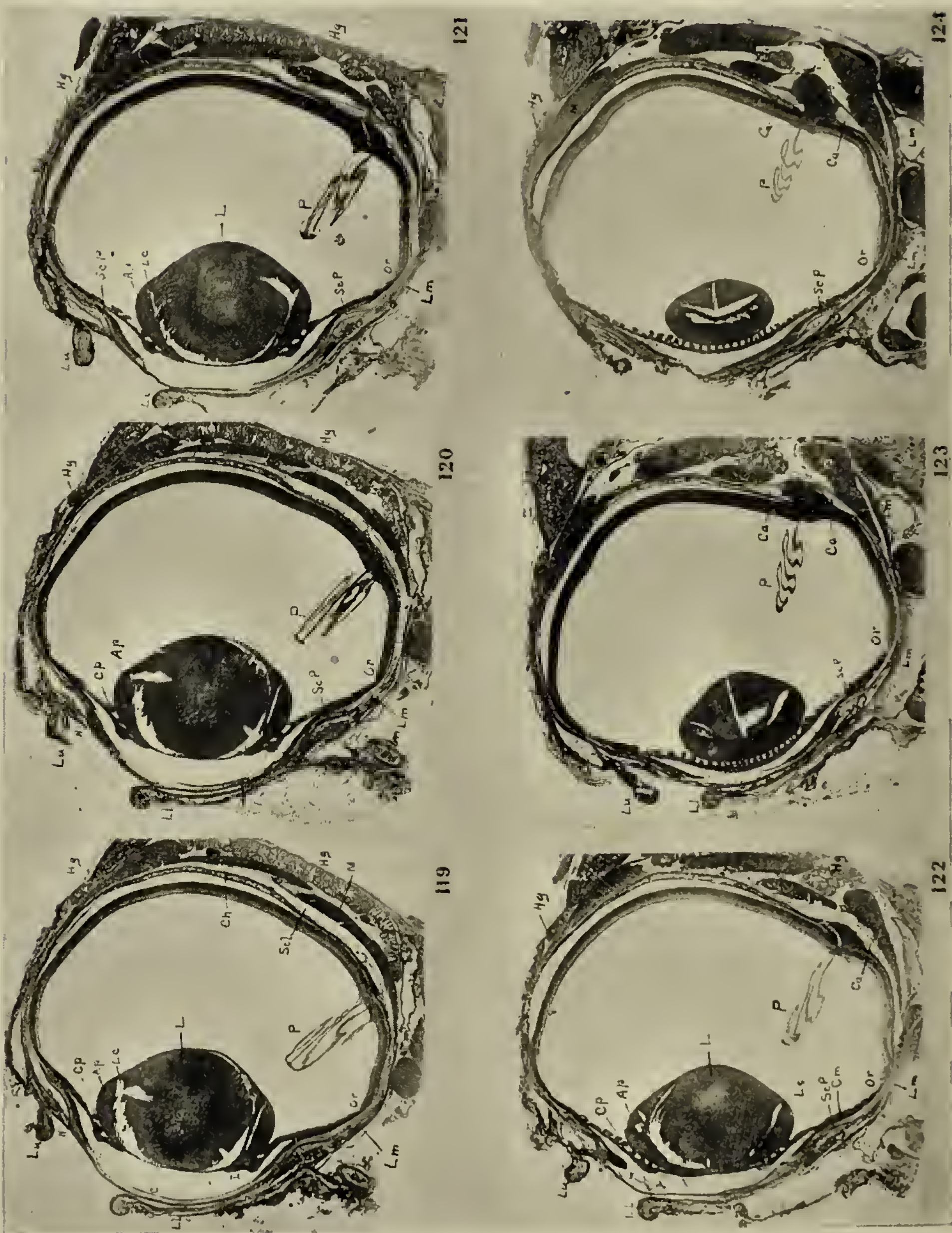
Sludnizka and further commented on in Vol. II of the *Encyclopédie Française d'Ophtalmologie.*

In the Lamprey *(Petromyzon planeri)* there is a singular formation of which the embryology of the parts gives the explanation. In the adult the nerve is enclosed in a thin fibrous envelope (folded upon itself) and formed by an elongation of the pia-mater. The axis of the nerve is occupied by a thick cellular cord made up of spindle-shaped cells, with the long axis transverse. The extremities of the cells give off fine elongations which are directed towards the external envelope

Pecten of Rhea. (After Parsons.)
Section of head of optic nerve, with the pecten attached to it and stretching forward into the vitreous. Note that the retina, seen folded to the left, is devoid of bloodvessels.

and separate the surrounding nerve fibres. These cells present the characteristics of spider-cells and they represent an elongation of the cells of the ependyma which connect the retina with the ventricular ependyma. The nerve fibres group themselves around this rod to reach the retina.

The optic nerve of Fishes. In a transverse section of the optic nerve of the Pike, it appears to be surrounded by a hard fibrous sheath from the internal surface of which are detached very thin connective partitions which serve to support the bloodvessels. The plexus which these partitions form is quite visible in sections taken at the periphery of the nerve cord, but it becomes less distinct towards the center.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Microphotographs of a Vertical Section of the Right Eye of a Young Sparrow Just Flying, Showing the Arrangement and Position of the Nerve Entrance at Different Levels. (Wood and Slonaker.)

Ap, Annular pad of the lens; *C*, cornea; *Ca*, thickened portion of the scleral cartilage surrounding the optic nerve entrance; *Ch*, choroid; *Cm*, ciliary muscle; *Cp*, ciliary processes; *Hg*, Harder's gland; *I*, iris; *L*, lenticular portion of the lens; *Lc*, lenticular chamber; *Ll*, lower lid; *Lu*, upper lid; *Lm*, muscle of the lower lid; *M*, eye muscles; *N*, nictitating membrane; *Op N*, optic nerve; *Or*, ora serrata; *P*, pecten; *Sc P*, scleral plates; *Scl*, sclerotic.

Fig. 119.—Section showing the distal and optic nerve piercing the retina only. x 10.

Fig. 120.—Section showing the distal and optic nerve piercing the retina and choroid. x 10.

Fig. 121.—Section showing the optic nerve lying just under the sclerotic. x 10.

Fig. 122.—Section showing the thickened scleral cartilage over the optic nerve. This portion of the nerve still lies within the sclerotic but pierces both the retina and choroid. x 10.

Fig. 123.—This section shows the optic nerve piercing the retina, choroid, and the thickened scleral cartilage, but is still covered by the outer membranous part of the sclerotic. x 10.

Fig. 124.—Section nearer the proximal entrance of the optic nerve. At this point the nerve pierces all the coats of the eye except the outer membranous portion of the sclerotic, which is extended out about the nerve forming its sheath. x 10.

Properly speaking, there is, in the Fish, none of the usual divisions into pencils of the mass of axis cylinders.

More often there project from the internal wall of the connective envelope dissepiments whose number varies with the species of Fishes. These dividing sheaths penetrate the nerve mass without traversing it completely, and appear like a band of cloth folded several times upon itself.

In the Eel, the nerve is divided into two large bundles by a partition which runs from one wall of the envelope to the other. From this main partition small partitions force themselves into the nerve mass, but they do not separate it into completely isolated pencils. In Silurians, one degree higher, in the animal orders, complete partitions are more common, especially at the inferior extremity of the nerve. In the Dipnoi, intermediate between Fishes and Amphibians, this partitioning is quite common.

Amphibians. In the larvæ of the Triton, of the Salamander, is found an embryonic cellular cord which, as described, occupies an axial position in the Lamprey. In the adult are found many neurolgia cells. There is, however, no formation of nerve pencils separated by complete partitions.

The optic nerve of Reptiles. The primitive embryonic groove extends the whole length of the optic nerve in the Tortoise. The connective tissue penetrates this fissure and binds the vessels to the nerve. In a cross section of the nerve there appear numerous neurolgia cells.

In Saurians the nerve is partitioned by anastomosing lines of glia cells. The optic nerve of Ophidia is separated into parallel pencils by lines of connective tissue derived from the enveloping pia-mater. A section of these pencils represents a series of polygons placed side by side; at the center of each polygon is a thick neuroglial cone bound to the periphery by radiating rectilinear fibrils. Greeff points out that the surface of the section gives a curious appearance of mosaic or tile-flooring.

The optic nerve of Mammals. The connective partitions in Mammalia are constant and more or less complete, especially towards the center of the nerve. Each nerve bundle is subdivided in turn by lines of neuroglia cells, which resemble the network found in Saurians.

In Man the neuroglia elements are found principally at the surface of the nerve bundles surrounded by complete connective partitions. See **Histology of the eye.**

THE OPTIC CHIASMA.

Decussation, or intercrossing, of optic nerve-bundles is a phenomenon common to all vertebrates. This cranial intercrossing may occur

within the wall of the third ventricle, as in the *Petromyzon,* or in the chiasma proper.

In the Bony Fishes the nerves, united by the neurilemma, simply cross one beneath the other; or, as in the Herring, one of the two nerves as a whole passes through the middle of the other by way of a buttonhole opening in the latter.

In the Selachians, the Dipnoi and the Ganoids each nerve is divided into several bundles which intercross with the corresponding and opposite pencils, like the fingers of two intertwined hands.

In Amphibians, Reptiles and Birds each nerve divides into superimposed ribbons or leaves, which intercross successively with those on the opposite side. Each leaf is formed of bundles enclosed in a thick neurilemma in continuity with the dissepiments previously described as seen in the interior of the optic nerve. The union of these thick sheaths with the bundles gives the chiasma of Birds and Amphibians a remarkable volume and cohesion.

In Mammals, on the other hand, the nerve pencils are destitute of connective tissue envelopes and an exact determination of their courses is extremely difficult. No division into bundles, layers or leaves can be seen: the nerve-mass at the outset divides into narrow, ribbon-like bundles, which, in crossing, give the appearance of basket-work or of a plaited tissue, with numerous layers superimposed.

As one proceeds still higher in the vertebrate scale the optic nerve has a tendency to separate into finer and finer bundles, and these bundles are in the Primates, for example, reduced to only a few fibres which decussate with those opposite. It is likely that in some animals the problem of complete or incomplete decussation in the tissues of the chiasma will for a long time remain unsolved.

By the aid of methods of Golgi and Ehrlich, Cajal has studied the course of the optic fibres in the lower vertebrates.

The Teleostean Fishes show a total decussation. The nerve fibres, very different in size, do not show divisions. It is the same in Batrachians, Reptiles and Birds.

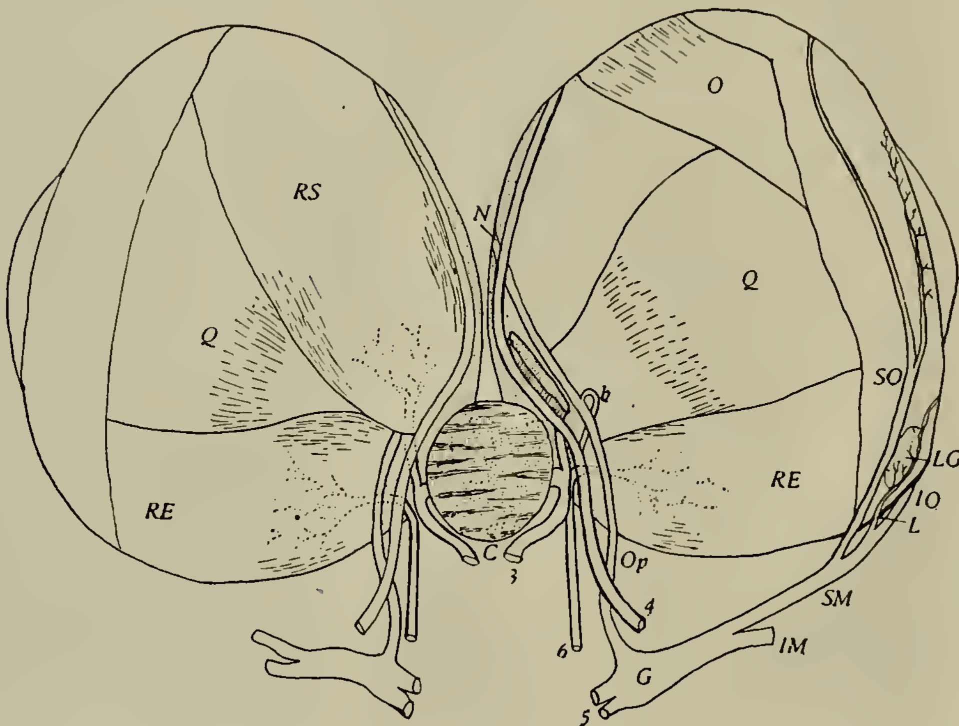
According to Franz, the optic chiasm in Birds presents uniform conditions, i. e., the optic nerve invariably divides into a number of similar ribbons or leaves which cross each other like the fingers of two interlocked hands.

Singer and Münzer, who have investigated this subject, find the number of decussations in Strix ulula to be only two; in Strix noctua five (Michel), 4 to 5 in Anas (Scheel), 5 to 6 in the Buzzard (Leuckart); in diurnal and nocturnal birds of prey according to Scheel 9 to 12; in the Jackdaw there are as many as 17 to 18 very thin leaves.

It seems, therefore, that the visual activity is one of the things upon which the number of intercrossing ribbons of the chiasma depends.

That the crossing is total in Birds has, in spite of the dissenting opinion of Munk, been proven by many investigators.

Kalt does not believe that the chiasma of Birds shows any evidence of a bifurcation of the decussating fibres or of commisural fibres passing from one retina to another.



Posterior View of the Eyes of the Sparrow after the Brain and Skull and the Lower Mandible have been Removed to Show the Relations of the Different Parts. The Superior Rectus of the Right Eye has been removed to Show the Nerves and Muscles lying Beneath. x 10. (Wood and Slonaker.)

C, Optic chiasma; *b,* branch from the ophthalmic to the third nerve; *G,* Gasserian ganglion; *IM,* inferior maxillary; *IO,* inferior orbital; *L,* lachrymal nerve; *LG,* lachrymal gland; *n,* nasal nerve; *O,* superior obliques; *Op,* ophthalmic nerve; *Q,* quadratus; *RE,* rectus externus; *RS,* rectus superior; *SM,* superior maxillary; *SO,* superior orbital; 3, 4, 5 and 6, third, fourth, fifth and sixth nerves.

According to Guelden the same is true of Owls, with their binocular vision.

In some cases the anterior part of the chiasma shows long spindle-formed nerve cells with large bifurcated and varicose dentrites. Their similarity with those of the tuba cinereum suggests that they represent dislodged cells of that organ, or from the region called the *grey roots of the optic nerve.*

In the Mouse and the Rabbit very few fibres escape decussation; but the existence of these non-crossing fibres is certain as was well

shown by Nicati (as long ago as 1878) in the chiasma of the Cat. These fibres follow the lateral margin of the optic nerve, pass along the external margin of the chiasma and finally reach the anterior part of the optic tract. Bifurcated fibres are also seen in the chiasma of the Rabbit and the Cat, each of the two branches entering a different optic tract. In the embryo of the Sheep, Köllicker was able to determine a direct passage of fibres into the fascieuli of the same side. The same conditions are present in the Calf and the Pig.

CILIARY (OR LENTICULAR) GANGLION IN BIRDS.

The nerve supply of this ganglion is different from that of Man. It will be remembered that the long, sensory root of the human ganglion is derived from the nasal nerve. Close by (in some cases incorporated with it), is a sympathetic root from the cavernous plexus. Its motor root is a short, rather thick twig from that muscular branch of the third nerve which is supplied to the inferior oblique muscle.

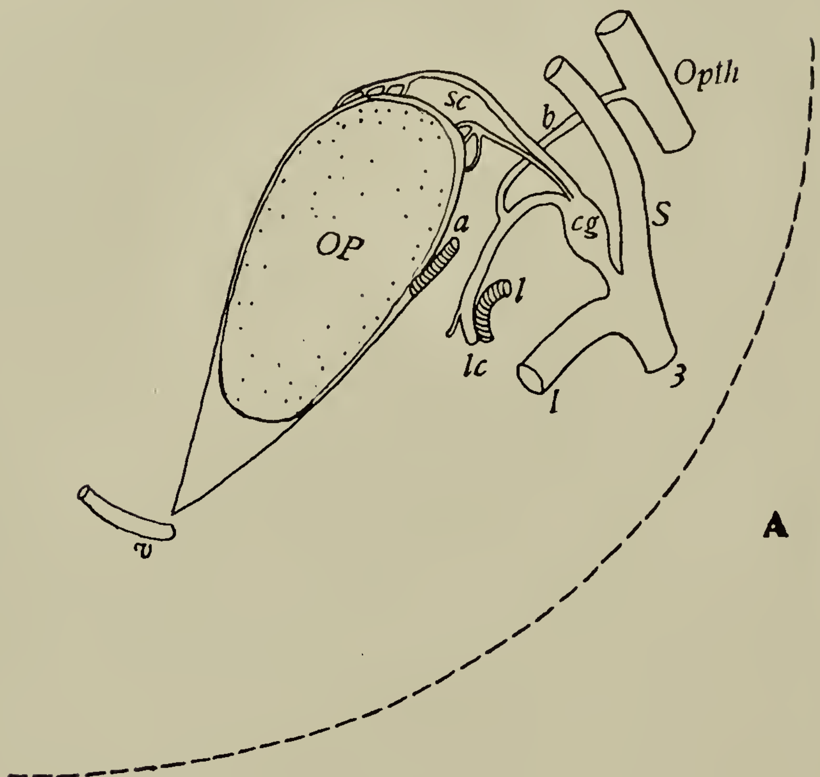
The ciliary ganglion in the sparrow is situated between the external rectus, globe and optic nerve, on a short branch of the superior division of the third nerve. (s and cg.) This is markedly different from that described in the Hen by Lenhossék (Das Ganglion ciliare der Vögel; *Arch. f. mikros. Anat. u. Entwickl.*, Vol. 76, No. 41, pp. 745-769, 1911) and Carpenter (The Ciliary Ganglion of Birds; *Folia Neuro-Biologica,* Vol. V, No. 7, pp. 738-754, 1911), who state that the ganglion is on a main branch of the third nerve.

Slonaker and the writer of this section found that in the sparrow two nerves of about equal size are given off from the distal margin of the ganglion, *one passing dorsally, the other ventrally.*

The dorsal branch soon divides into two nerves of unequal size (sc) which pierce the sclerotic at two distinct places close to the dorsal margin of the optic nerve entrance. These branch out between the choroid (in which they are partially imbedded) and the sclerotic as the short ciliary nerves.

The ventral branch from the ciliary ganglion (bc), after receiving a small ramus from the ophthalmic division of the fifth (b), pierces the sclera a short distance posterior to the median portion of the optic nerve. Internally, this nerve emerges from the sclerotic as two flattened branches that lie closely adjacent to the sclerotic, and run forward side by side as the long ciliary nerves to supply the anterior part of the eye.

In the Hen, Lenhossék describes two branches of unequal size leaving the distal portion of the ganglion, each of which enters the eyeball a short distance past and close to the optic nerve entrance. The



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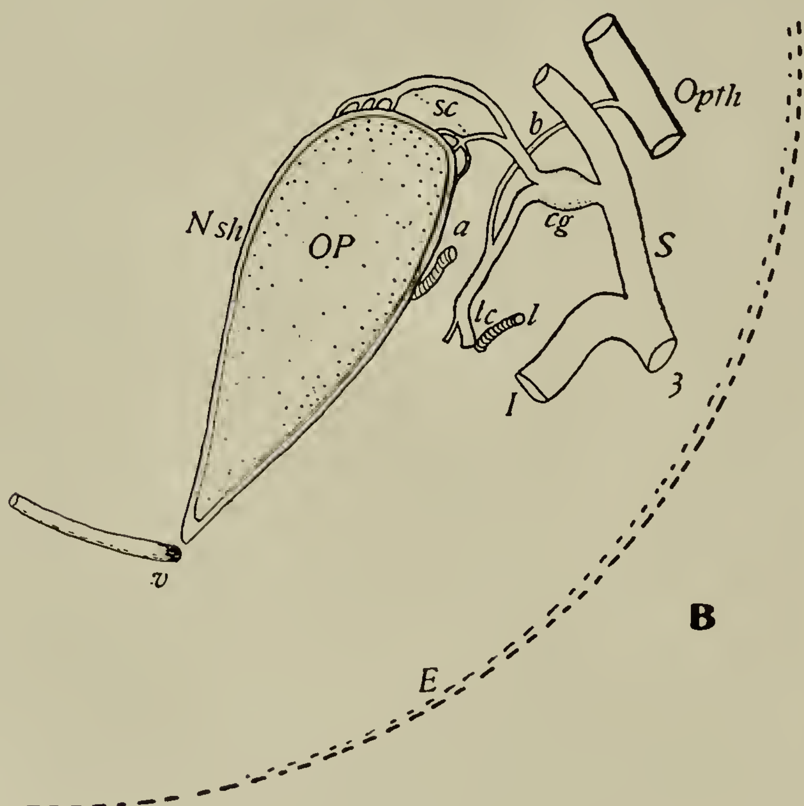
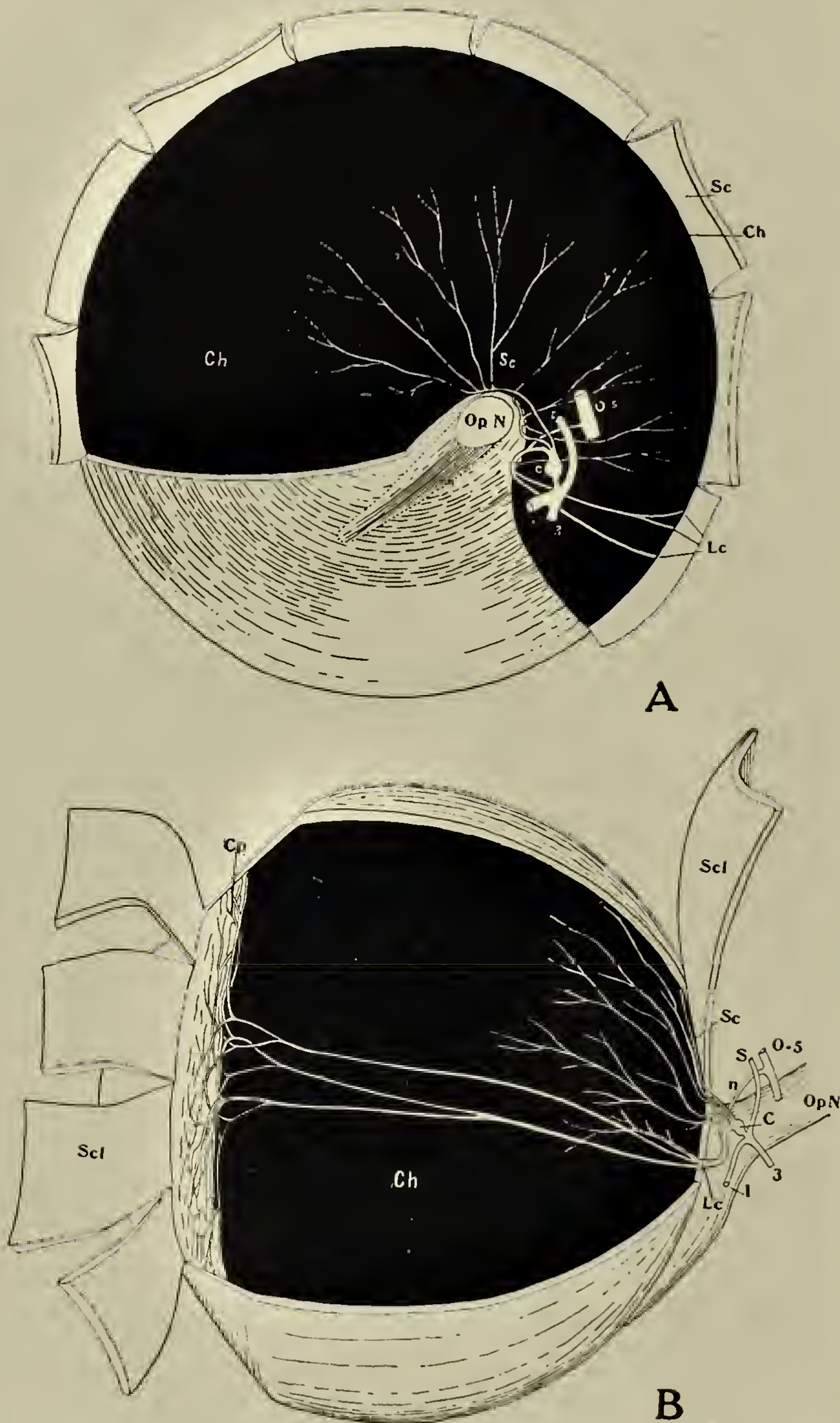


B

Posterior View of a Portion of the Right Eyeball of the Sparrow after Removal of the Muscles Showing the Ciliary Ganglion and its Relations to the Various Nerves. A and B show Variations in the Branches of Nerves. x 20. (Wood and Slonaker.)

a, Artery which pierces the sclerotic at the angle of the sheath of the optic nerve and the sclerotic to supply the pecten; *b*, branch from the ophthalmic nerve; *cg*, ciliary ganglion; *E*, margin of the eyeball; *I*, inferior branch of the third nerve; *lc*, long ciliary nerve; *N sh*, sheath of optic nerve; *Ob*, *Ophth*, ophthalmic branch of the fifth nerve; *s*, superior branch of the third nerve; *v*, point of emergence through the sclerotic of the vein from the pecten; 3, third nerve.

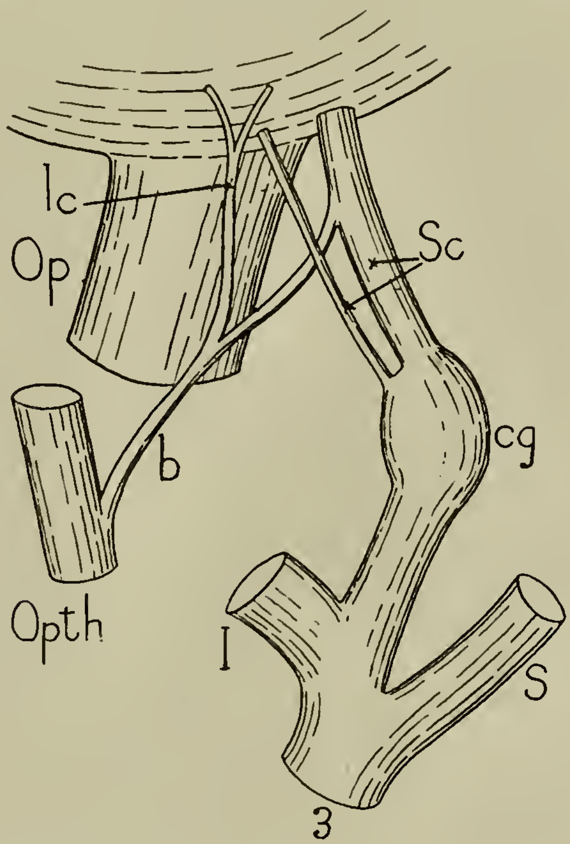


Drawings from a Dissection Showing the Distribution of the Long and Short Ciliary Nerves of the Right Eye of the Sparrow. x 20. (Wood and Slonaker.)

A, Posterior view; B, side view; C, Ciliary ganglion; Ch, choroid; Cp, ciliary plexus in ciliary region; I, inferior branch of the third nerve; Lc, long ciliary nerves; n, branch from the ophthalmic nerve connecting with the third; Op N, optic nerve; O-5, ophthalmic nerve; S, superior branch of the third nerve; Sc, short ciliary nerves; Scl, sclerotic; 3, third nerve.

larger of these branches is joined by a ramus from the ophthalmic. Carpenter describes in the Hen but one nerve leaving the distal portion of the ganglion, which, after receiving the twig from the ophthalmic, runs direct to the eye-ball. From microscopical examination he shows that this one nerve is made up of a variable number of small fibre bundles which arise from the main nerve as it leaves the ganglion, and that one or more of these smaller nerves may leave the ganglion independently. (See the accompanying figures.)

Each of these authors has also described a small nerve, given off from the ramus of the ophthalmic to the third, as the long ciliary



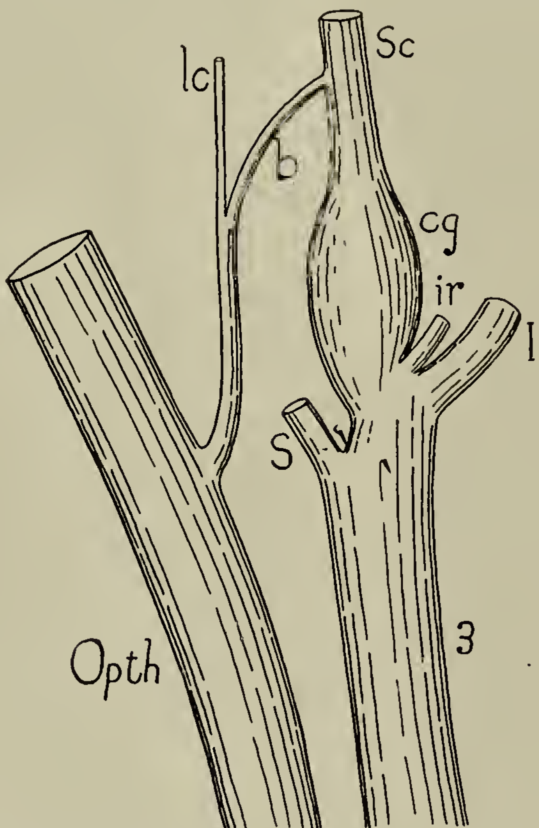
Relations of the Ciliary or Ophthalmic Ganglion, According to von Lenhossék. *lc*, Long ciliary nerve; *Sc*,

nerve. Slonaker and the writer have not been able to demonstrate such a branch in the Sparrow. Owing to the minute size of these branches in a small bird like the Sparrow it is possible to destroy such a branch during dissection or to overlook it even with the exercise of considerable care and the constant employment of the binocular dissecting microscope.

The *ciliary ganglion* derives its branches to a large extent from the third nerve in the Sparrow. A branch to the ciliary ganglion starts either from the superior branch of the third, or it may come from the

angle where the superior and inferior branches of the third divide. In no ease does it originate in the inferior branch.

Von Lenhossék and Carpenter have pietured in the Hen the nerve supply to the ganglion as arising from the inferior branch of the third nerve, either elose to it, or in the angle made by its division into the inferior and superior branehes of the third nerve. Carpenter pictures (see the figure) but one braneh leaving the eiliary ganglion, which is soon joined by a braneh from the ophthalmie nerve, to pierce the selera and form the short eiliary nerves. Von Lenhossék describes



Relations of the Ciliary or Ophthalmic Ganglion, According to F. W. Carpenter. *lc*, Long eiliary nerve; *Sc*,

two nerves of unequal size leaving the ganglion whieh later pieree the selera, and form the short eiliary nerves. The larger of these two branehes is joined, just before it reaches the eye-ball, by a branch from the ophthalmie nerve. Each of these authors deseribe this branch (from the ophthalmie nerve) as dividing, one of the resultant twigs entering the eye and forming the long eiliary nerves, the other joining the aforesaid nerve from the eiliary ganglion.

In the Sparrow two branehes—a superior and an inferior—leave the ciliary ganglion. They are of about the same size.

The superior division sub-divides into two branehes of unequal size,

the smaller piercing the sclerotic at the upper, posterior margin of the optic disk. In its turn it divides, either before or after piercing the sclera, into three short ciliary nerves. The largest superior twig of these pierces the sclera close to the anterior upper margin of the disc, either as four separate nerves or it divides in the substance of the sclera into four short ciliary nerves.

The inferior branch from the ganglion is joined, a short distance beyond, by a small branch from the ophthalmic nerve. Passing ventrally, it divides into one small and one large nerve, each piercing the sclera posterior to the middle portion of the optic disc. The smaller branch forms the eighth short ciliary nerve, while the larger branch divides and forms the two long ciliary nerves. In no case was the connecting nerve between the ophthalmic to the third nerve found to divide in the Sparrow, as described by Carpenter and Von Lenhossék in the Hen.

F. W. Carpenter, who has carefully worked out the anatomy and histology of the ciliary ganglion also in the Pigeon and Duck, substantially agrees with the findings of Von Lenhossék in the case of the Hen.

Carpenter gives as follows a résumé of the work:

1. The ciliary ganglion of birds is closely related to the oculomotor nerve. In the Hen, Pigeon and Duck the ganglion is situated directly *on* the trunk of the nerve, i. e., no short root normally exists.

2. The ganglion gives off from its distal end one large nerve and a variable number of smaller ones. These together constitute the *nervi ciliares breves* (short ciliary nerves).

3. A communicating ramus from the ophthalmic division of the trigeminus joins the short ciliary nerves not far from the ganglion. About three-fourths of the fibres of this ramus accompany the short ciliary nerves to the eyeball *(nervi ciliares longi)*. The remaining fibres turn caudal and enter the distal end of the ganglion, thus forming a *radix longa.*

4. A sympathetic root is not present.

5. The cells of the ciliary ganglion are unipolar. Their unbranched processes (neurites) pass distally to form the short ciliary nerves. The cell bodies are enclosed in capsules with amphicyte or satellite nuclei.

6. Large, well medullated fibres from the oculomotorius enter the proximal portion of the ganglion and terminate on about three-fourths of the cells in calyx, brush or arborescent endings. Whether these fibres ever terminate in true end nets is doubtful. The portion of the ganglion supplied by the oculomotor nerve is characterized by the

presence of coarse, heavily medullated neurites and the peculiar endings just mentioned. It may be designated the *oculomotor region.* The short ciliary neurites emerging from this region are of small caliber, but have comparatively large medullary sheaths.

7. Fine, weakly medullated fibres forming the *radix longa* from the ophthalmicus enter the distal portion of the ganglion, and terminate on cells here in the form of delicate end nets. This may be called the *trigeminal* region. Heavily medullated fibres and the endings peculiar to the oculomotor region are absent. The short ciliary neurites emerging distally are less well medullated than those from the oculomotor region, and often form a special bundle running as a small *nervus ciliaris brevis* to the eyeball.

8. The failure of nicotine and removal of blood to paralyze the ciliary ganglion of birds is probably due to the calyx endings which intimately bind together the oculomotor and ciliary neurones.

9. The trigeminal fiber system (*radix longa* and short ciliary neurones) appears to be motor in function, and to control the dilator muscle of the iris. The morphological and experimental evidence at command points to the cerebro-spinal (trigeminal) nature of the fibers of the radix longa rather than to their sympathetic nature.

10. The ciliary ganglion of birds is not cerebro-spinal, nor, strictly speaking, sympathetic. It appears to be a purely motor ganglion, with peculiar histological characters, belonging to the mid-brain and bulbar subdivisions of the autonomic nervous system.

F. R. Cross (*Lancet,* Dec. 18, 1909) in discussing the comparative anatomy of the brain structures concerned in vision finds that in Fishes the visual organs are well developed, and vary in importance with the necessity in the species for more or less perfect sight: optic lobes and tracts, an optic chiasma and infundibulum, a third, fourth, and lateral ventricles and corpora geniculata underneath the optic thalamus. These often vary conversely in importance with the olfactory region, which is enlarged when smell is the more needed function. In all fish the optic nerves cross quite separately one above the other, from one eye to the opposite optic lobe, or one nerve may pass through a slit in the opposite one.

In Amphibians the brain is usually of low type but rather large. In Proteus, which is practically blind, the optic lobes are scarcely recognizable, but in the Frog they are large and form the broadest part of the brain. In Reptilia the brain is long and narrow, but it has become much increased in size and is well differentiated, and there is a very definite cerebral cortex. The three mantles of the brain exist as found in mammals: (1) the basalpallium or pyriform; (2) the

marginal pallium or hippocampal; and (3) the neopallium or higher cortex (brain proper).

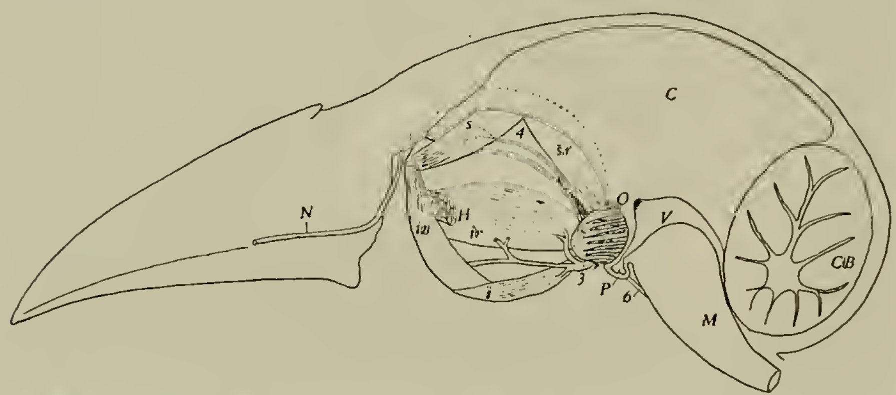
The brain in Birds is broad and highly developed, enlarged chiefly by the size of the corpora striata. All the structures upon which sight depends are very well developed. The thalamus and optic lobes are highly organized, and there are even present small temporal and occipital lobes. In birds the optic chiasma is single and complete and crosses over the infundibulum. The bundles of fibers from each optic nerve interlace and alternate, but those of each nerve completely decussate to the opposite side. The optic tracts pass round the optic thalami and show well-developed geniculate bodies. In birds of prey, where rapid co-ordination between the seeing and capturing of their prey is essential, the optic lobes are very strongly developed. Vision is, as a rule, panoramic, one eye for each side. (The fowl sees its food one eye at a time.) In owls and hawks, whose eyes look forward and which undoubtedly possess a considerable field of binocular vision to enable them to catch their living prey, probably no fibers from the optic nerve pass direct without decussation. There vision is binocular, but not stereoscopic, for which direct as well as decussating fibers are required.

Cross finds in Marsupials the brain becomes still more highly organized. On the mesial surface of the hemispheres there appears a sulcus which runs horizontally behind and parallel with the hippocampal. This is the calcarine, or splenial, about which the cortical substratum for vision is placed; it is one of the earliest, best defined, and most constant fissures of the brain, and it can already be shown to form the calcar avis in the ventricle. A genual and a rostral sulcus also show on the mesial surface of the hemisphere, although no corpus callosum as yet exists.

When we reach the Placental Mammals a corpus callosum becomes developed and completes the three great commissures with the anterior and the hippocampal. In the Colugo (Insectivora) the sulci on the brain become more marked; the most definite is a deep calcarine sulcus running horizontally forward, almost the whole length of the mesial surface of the hemisphere; there are also very large anterior quadrigeminal bodies. In the many families of rodents there is a peculiar absence of sulci, especially on the mesial aspect of the brain, and the calcarine fissure is rarely seen. The squirrel requires very accurate sight, and he has large optic nerves and very well developed anterior quadrigeminal bodies. The rabbit and the hare probably possess a very acute sense of hearing. They live to avoid being captured. The eyes are placed so much on the side of the head that each carries an

enormous range over its field of vision, and they can see laterally and behind almost as well as in front. This wide panoramic vision cannot well be associated with any great binocular effort; nearly all the optic nerve fibers decussate.

In the Carnivora the brain proper is highly developed; it passes forward over the olfactory bulb and backward over the cerebellum. There is a very high degree of binocular vision. In the fruit-eating carnivora the eyes are at the side of the head and they possess only a limited convergence. But in the Felidæ and others the eyes are set forward and the pupil is very active. These animals require good distant vision, often when the light is dull, and they also need very reliable closer sight and a most perfect co-ordination of the eyes with the fore limb, by which they catch their prey. In the optic chiasma



The Median Section through the Sparrow Head, Showing Relations of the Different Parts. The Lower Mandible and the Ventral Portion of the Skull has been Removed. x 6. (Wood and Slonaker.)

C, Cerebrum; *CB*, cerebellum; *H*, Harder's gland; *i*, inferior rectus; *in*, inferior oblique; *ir*, internal rectus; *M*, medulla; *N*, nasal nerve; *O*, optic nerve; *P*, pituitary body; *s*, superior oblique; *sr*, superior rectus; *v*, third ventricle; 3, 4 and 6, third, fourth and sixth nerves.

there are very many direct as well as decussating fibers. There is a deep calcarine sulcus which with the intercalary shuts off a posterior lobe from the rest of the brain. In some species there appear secondary fissures, running out of the calcarine or even a definite retrocalcarine.

The Ungulata are large animals and they need a large brain, but the mesial area is very simple. There is no high specialization in the calcarine fissure; it is large and placed behind the splenium. It joins the intercalary and this the genual, showing a complex splenial or a form of cingular arc. The eyes are usually placed on the side of the head and separated by the forehead or nose. There is a wide area of periscopic sight, but they have only a limited amount of convergence and binocular vision. In the horse about one-sixth of the fibers decussate.

Cross further remarks that in periscopic vision each eye is responsible for the field on its own side, and as this is represented on the opposite side of the brain all the optic nerve fibers must decussate. When the eyes tend to converge and give slight binocular vision a part of the nasal side of each field is overlapped. The superimposed parts have crossed to the opposite side of the middle line. The extreme nasal side of the right field is now concerned with the left field of vision, and the fibers that represent this must go to the opposite side of the brain. As the eyes turn more forward, more and more of the nasal fields overlap, and more and more direct fibers are required. In perfect stereoscopic vision both visual axes must be turned towards the object looked at. The whole nasal field is carried across the middle line; we thus have an almost complete overlapping of the two fields, and, what is more important, overlapping of the objects seen by the two maculæ.

In Monkeys the calcarine sulcus becomes the center of further development. In the aye-aye and lemurs it is somewhat vertical, but in the tamarin, one of the anthropoid apes, and marmoset, a long single sulcus is prolonged horizontally far back into an elongated occipital lobe, which measures nearly half of the brain. In the squirrel monkey (Cebidæ) almost half the hemisphere lies behind the splenium. In this large occipital lobe the calcarine sulcus terminates in a wide-shaped bifurcation, and several other compensatory calcarine sulci are developed. The collateral runs forward on its ventral side, and from its dorsal runs up a parieto-occipital sulcus close behind the intraparietal.

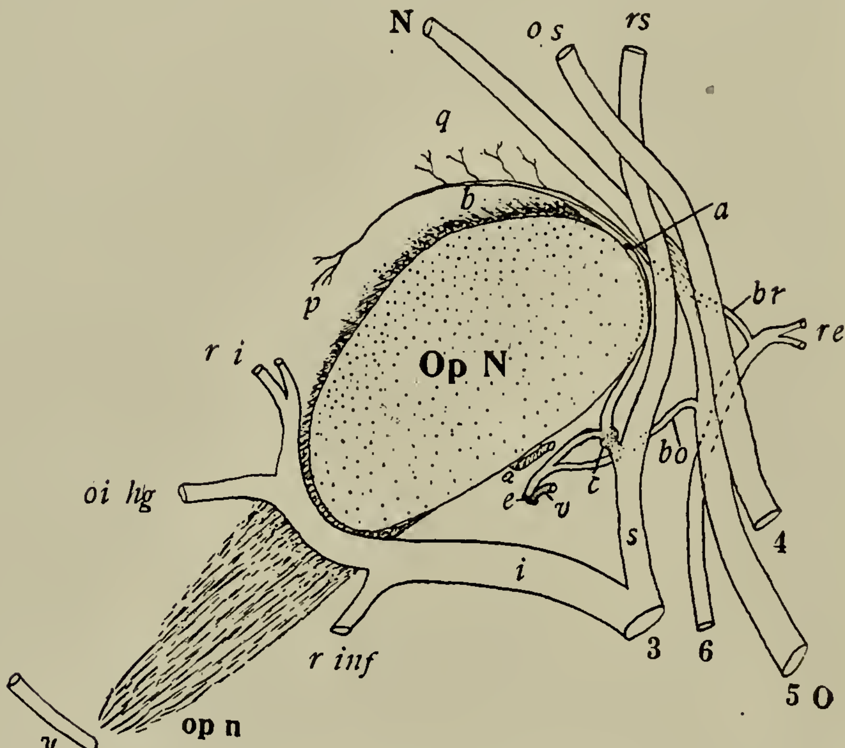
Students who desire to investigate more fully the comparative histology and physiology of the cerebral tracts and centres concerned in vision are especially referred to the writings of Edinger, Cajal and Kölliker, a good abstract of which will be found in Vol. II of the *Encyclopédie Française d' Ophtalmologie.*

THE MOTOR NERVES OF THE EYE.

The common ocular-motor exists in all vertebrates. Its emergence is on the ventral side of the mid-brain. Its terminals in the muscles of the eye seem to indicate a purely motor rôle. However, in Selachians there are ganglion cells in its interior. It is the same in Amphians and in some Sauropsidia, while in others these cells are included in a ciliary trunk coming from the third pair. Finally, in Mammals there appears the ciliary ganglion to which this nerve furnishes a thick short root.

The oculo-motor innervates, as in Man, all the ocular muscles except the superior oblique and the external rectus.

The apparent origin of the fourth cranial or *pathetic nerve* is upon the posterior face of the mid-brain, although its real origin is behind the oculomotor. The pathetic possesses both sensitive and motor nerves in the Ganoids, the Selachians and Anoura. In the latter it also sends branches to the conjunctiva. In Urodèles this nerve is sometimes replaced by a twig of the ophthalmic branch of the trigeminal.



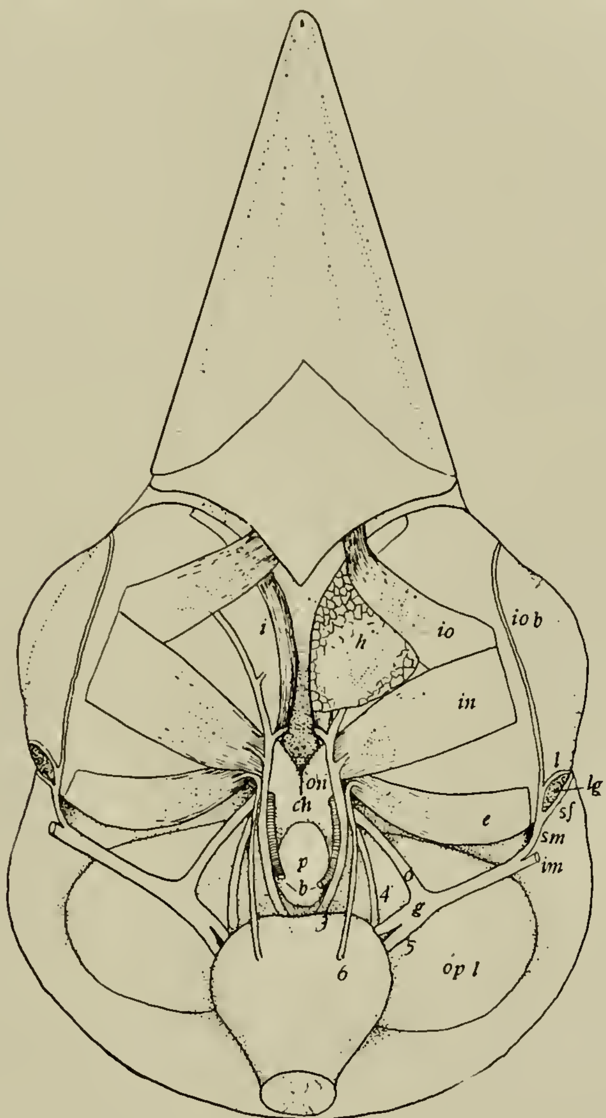
Enlarged View Showing the Relative Positions of the Nerves of the Eye in the Sparrow. (Wood and Slonaker.)

a, Point where the superior branch from the ciliary ganglion penetrates the sclerotic; *b*, branch from the sixth nerve to the quadratus and the pyramidalis; *c*, ciliary ganglion; bo, branch from the ophthalmic to the inferior branch of the third; *e*, where the inferior branches from the ciliary ganglion enter the sclerotic together with a small blood-vessel, *v; i*, inferior branch of the third; *N*, nasalis; *p*, to the pyramidalis; *q*, to quadratus; *Op N*, optic nerve; *os*, to the superior oblique; *oi*, *hg*, to the inferior oblique and Harder's gland; *re*, to the external rectus; *ri*, to the internal rectus; *r imf*, to the inferior rectus; *rs*, to the superior rectus; 3, third nerve; 4, fourth nerve; 5 O, ophthalmic branch of the fifth; 6, sixth nerve.

The anastomoses between the pathetic and the trigeminal are variable; the two nerves often leave the cranium by the same orifice. There exist sometimes anastomoses with the sixth pair.

The sixth or external oculomotor nerve has its apparent origin far back, on the lower surface of the elongated medulla. In the Lamprey, it is blended with that of the trigeminal.

The sixth nerve, in the majority of vertebrates, issues from the cranium separately, or it unites with the second and the third braneh of the trigeminal. Sometimes it loses itself in the ganglion of Gasser



The Ventral View of the Base of the Brain of the Sparrow, the Eyes and the Nerves Supplied to the Eyeball and Appendages. The Harderian Gland of the Right Eye has been Removed to Show the Internal Rectus. x 6. (Wood and Slonaker.)

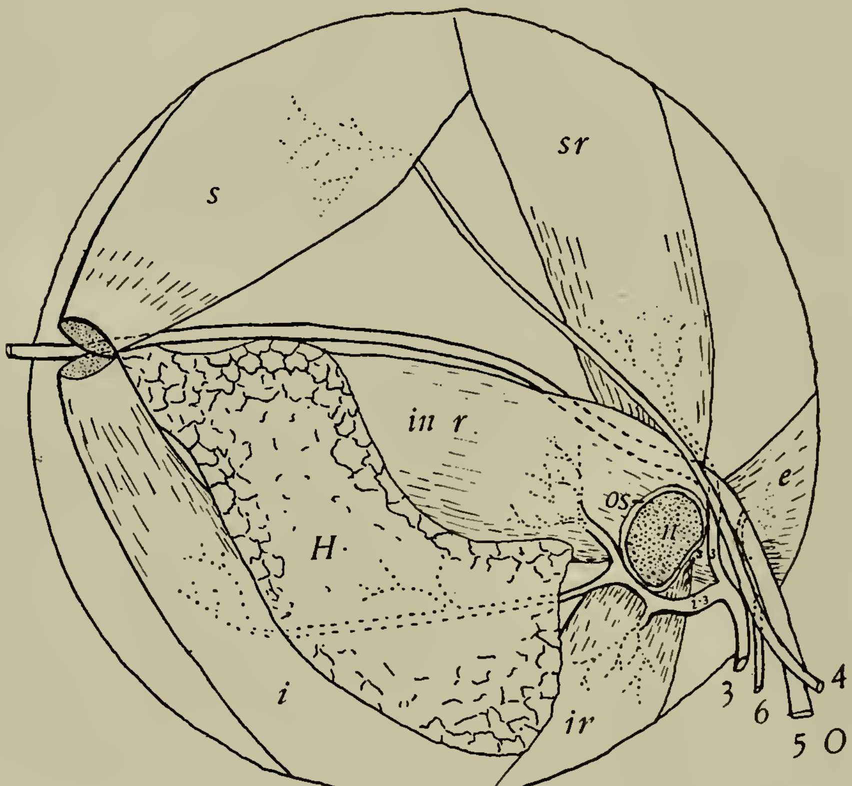
b, Blood-vessels; *ch*, chiasma; *e*, external rectus; *g*, Gasserian ganglion; *h*, Harderian gland; *i*, internal rectus; *im*, inferior maxillary nerve; *in*, inferior rectus; *io*. inferior oblique; *io* b, inferior orbital nerve; *lg*, lachrymal gland, *l*, lachrymal nerve; *o*, ophthalmic branch of the fifth nerve; *on*, optic nerve; *op l*, optic lobe; *p*, pituitary body; *sf*, superior orbital or frontal nerve; *sm*, superior maxillary; 3, 4, 5, and 6, third, fourth, fifth and sixth cranial nerves.

and is found again further on, leaving the ophthalmie branch to join the external reetus musele.

Besides the external reetus, the sixth pair innervates the retraetor

muscle of the eyeball and the motor muscles of the third eyelid in Reptiles and Birds.

Several of the *oculomotor nerves in Birds,* as they leave the cranium and before their supply to the muscles, are protected from injury in tubes of bone. These tubules cover the nerve much as an iron or lead pipe is made to protect underground or subaqueous electric wires or cables. The need of this form of protection is due to the lack in Birds of a closed bony orbit, such as is found in Man and many other



Posterior View of the Sparrow's Eye, Showing the Normal Relative Position of Nerves, Muscles and Glands. x 10. (Wood and Slonaker.)

e, External rectus; *H,* Harder's gland; *i,* inferior oblique. *in r,* internal rectus; *ir,* inferior rectus; *n,* optic nerve; *os,* sheath of the optic nerve; *s,* superior oblique; *sr,* superior rectus; 3, third nerve with its inferior *(i-3)* and superior *(s-3)* branches; 4, fourth nerve; 5 *O,* ophthalmic branch of the fifth nerve; 6, sixth nerve.

vertebrates. This condition makes it difficult to carry on a dissection of the nerve, for the removal of the bony casing may easily lead to rupture of its nervous inclosure. In the case of the sixth nerve this osseous tube is about 3 m. in length.

VISION AMONG VERTEBRATES.

The visual acuity. If left to a superficial observation one might believe that animals are endowed with a high degree of that faculty of of separation of two points close together, which is known as visual

acuteness. It is known that in man form-perception does not really exist except at the fovea and its immediate neighborhood. Dufour and Kalt calculate that for a deviation of 10° from this retinal point, the acuteness falls to 7/100 of normal; at 35° of deviation, the vision is reduced to finger counting; at 45°, objects are perceived very dimly. On the other hand, we distinguish perfectly the *displacement* of a point of light over the whole field of vision, and about as well at the centre as at the periphery. Foveal vision, then, helps us to distinguish details of objects; eccentric vision serves the animal in orientation and for the regulation of movements among nearby objects.

Of vertebrates, only the higher Monkeys and Birds appear to possess an acuteness of vision comparable to that of man; for this purpose both are provided with a well-developed fovea and a powerful accommodating apparatus. The monkey easily recognizes the characters of small objects close at hand; a bird quickly discovers a microscopical grain of millet at a short distance and unerringly seizes it in its beak; the sparrow-hawk soars high in the air and instantly recognizes a mouse or a young partridge at distances inconceivable to human beings. It is probable that birds become aware of the presence of their prey by the movements it makes on the ground; but it is not to be forgotten that at the distance of the bird the body of a mouse must appear as a minute grey spot.

Inferior vertebrates—Reptiles, the Batrachians and Fishes—seem to be guided by the movements which their prey makes. The Frog and the Serpent do not seize the animal which serves as food until it moves. A fish may often be approached quietly until it can be touched; but at the least sudden movement it darts away.

Nuel thinks that two arguments plead in favor of a certain degree of color perception and acuteness of vision in Fishes; first, a high degree of accommodation has been found among them; and second, fishermen, in catching them, require a varied collection (mostly colored) of artificial flies. However, it may be that these colored objects are seen in detail largely by their form and the movements they are made to execute.

The reviewer of Hess's *Vergleichende Physiologie des Gesichtsinnes*, 1912, in the *Ophthalmic Review* says of the writer's experiments in a dark chamber, that a bright spectrum is cast on the floor where some food stuff, such as wheat or rice, has been strewn, and the animal to be tested is allowed to approach the food, observations being made of the region of the spectrum from which it first picks the grains, and of the portions from which all the material is ultimately lifted. It is argued that the animal feeds first from the part of the spectrum

which is, to it, the brightest part, and that if any of the grain is left the rays by which it is illuminated are invisible to the animal in question. By this method, and by variants of it devised to suit the habits of different speeies, many interesting, and some surprising, results have been obtained. Thus it has been found that, to the monkey, the spectrum has the same length, and the same region of greatest brightness, as to the human being; that to birds and reptiles it is much shortened at the violet end, and appears as it would to a man wearing reddish-yellow glasses; and that in fish, and all the invertebrates, visual sensations are the same as those of a totally color-blind man. Thus Hess takes it as proved that color vision, in our sense, is eonfined to the air-breathing invertebrates, and that all other species are color blind. To reach sueh a position the author has had to attaek the long established belief, based on the researches of Lubbock and others, that bees and other insects have a sense of eolor, and that, indeed, the colors of flowers serve the purpose of attracting the insects whieh are the agents of fertilization. Probably the upholders of the latter view will not aceept Hess's results as the last word on the subject. It is admitted, for instance, that certain inseets show a preference for blue as against red, which, to us, is a brighter color. Hess maintains that the inseet prefers blue beeause, for it, it is the brightest part of the speetrum, and he was able to demonstrate that bees would migrate from a box illuminated with blue into a neighbouring one with red, if the brightness of the red was increased. But it is to be noted that the red light, whieh was already brighter than the blue to the human eye, had to have its brightness multiplied from nine to fifteen times before the bees transferred their affeetions. There seems to be something still unexplained in this question of the color sense of inseets, and one is reminded of Hess's own warning as to the extreme care that is necessary in the interpretation of the results of sueh experiments.

Another doetrine whieh he sets himself to overthrow is the theory of Loeb, that the movements of animals towards areas of greater brightness or of greater darkness, are of the same nature as the "heliotropic" movements of plants, which are under a sort of mechanical compulsion to grow towards the source of light. He points out that the animals in question, larvæ for example, do not move towards the source of light, and that the more highly refrangible rays of the spectrum do not act more powerfully on them than the rays of lower refrangibility. The terms "heliotropism" and "phototropism" which are already in use, do not express the idea which he wishes to eonvey, so he has coined the two words "lamprotrope" and "scototrope," for animals which move

respectively towards the brightest part of their spectrum and towards the darkest part of their spectrum.

Some popular beliefs regarding the vision of the lower animals also come in for the author's destructive criticism. We are assured, for example, that there is nothing in the wide-spread beliefs that bulls are excited by red, that fowls are night-blind, and that owls and other night birds are day-blind. One wonders how long it will be before these opinions of the author are accepted as parts of the body of popular belief.

Next in order come Carnivora, although with them the visual acuity, as well as the accommodation, is weak; a portion of their retina recalls the human macula, but the fovea is missing. It is quite likely that these animals are guided mostly by the displacements of objects. The Cat immediately fixes a mouse that appears in its field of vision, but it is hard to say with what nicety it distinguishes details; but we are better informed about the Dog. There is a popular idea probably well founded that the Dog sees badly; that he does not recognize his master at a short distance if the latter does not make familiar signals and takes care to keep out of his dog's scent.

Solipeds, Ruminants and Rodents see still worse than Carnivora. They distinguish roughly at a short distance objects that serve them as food, but as soon as the animal brings its mouth near them it is the sensation of touch furnished by the lips that serves as a guide.

It is well known that Deer and the Hare in the forest often approach quite near to the hunter; but at the least movement (or if the man gets to windward) his presence is discovered and the animal flees.

It has also been noticed that the eyeballs of these animals are almost immobile and that they have little power of accommodation.

In the writer's experience (Casey Wood, *Ophthalmology,* April, 1907) the refraction of birds' eyes is generally hypermetropic. In a large number examined by skiascopy he found, just as Lindsay Johnson discovered in mammals, that wild birds are invariably far-sighted, while domesticated species tend to become short-sighted, astigmatic, or both, and to present evidences of intraocular disease. This was especially true of the large collection of Owls in the London Zoological Gardens that he examined in the summer of 1905 with the ophthalmoscope and skiascope. Those Owls, it matters not what variety, that had lived in the gardens more than two years were generally less hyperopic than those recently introduced, while in the case of the former it was difficult to find one that had not a more or less marked form of choroiditis of the disseminate variety.

The estimation of distances in vertebrates. Berlin thinks that because of the distance between their eyes the Horse and other large Mammals are better provided than Man for the appreciation of the position of objects seen binocularly. In fixing objects at various distances, these animals are able to displace the lines of sight and describe visual angles much larger than those made by Man.

In the Bird, on the other hand, the ocular movements are limited. Although the eyes of the owl, placed side by side, are almost immobile, yet this bird possesses binocular vision of a quality similar to that of Man. Birds with a single fovea probably do not see binocularly yet their single vision is generally very acute. Everybody has seen birds turn their heads in different directions in order to bring within the line of vision some object that interests them. Thus reduced habitually to the use of one eye, the vision of the animal possesses nothing less than an astonishing precision, whether one considers the domestic fowl picking up minute seeds or grains of sand, or the insectivorous bird searching for its microscopical prey in the crevices of bark. It is also likely that the powerful and rapid contractions of the muscles of accommodation give it great assistance in estimating distances by the muscular sensations which they excite in the sensorium. It is also probable that the intra-ocular muscle supply in a certain measure supplements the sensations of the extrinsic muscles and the convergence.

We can hardly overestimate the importance of these sensations. The human, smooth, ciliary muscular apparatus requires one second to complete the adaptation of the eye through a distance of 30 centimeters between two points, one 43 centimeters distant, the other 13 centimeters distant from the eye. When one compares this adaptation with that of a swallow catching insects, when both hunter and prey are in full flight, one realizes the perfection which the accommodative mechanism of the Bird has reached.

The field of vision in Vertebrates. It will be recalled that the field of vision in Man extends over about 160° (100° temple-wards; 60° nasally) in the horizontal meridian. When the visual axes are parallel the binocular field of vision attains (2x60°=)120°. As each eye, taken separately, sees more than 40° farther (in the temporal sense) the total field of vision reaches 200°.

As Kalt points out, it is necessary to consider the relations of the cornea to the monocular field of vision. That this is about 80° in Man, it rises to 85° to 90° in the Monkey, 100° in Carnivora and 105° to 130° in Rodents.

The increase in corneal surface augments the clearness of the per-

ipheral image; if the size and shape of all animal corneæ were the same vision at the periphery would, other conditions being equal, also be of equal clearness.

The principal visual differences between the eyes of the lower animals and Man are due to an increase in the size of this angle. In the human species the visual axis pierces the cornea at 5° inside its centre. In the higher Monkeys it is almost the same; but one sees this angle increase as one descends the animal scale. It is 15° in the Lemuridæ, 20° to 26° in Carnivora, and it varies between 50° and 63° in Herbivora.

It is understood that the increase of this angle has the effect of balancing to a certain degree the increase in convergence of the orbital axes. Animals with eyes so disposed continue to see binocularly. The Lion, for instance, appears to have a binocular field of vision attaining 120°.

As the divergence of the ocular globes increases, the field of vision extends more and more posteriorly and the common anterior portion is reduced proportionally. The Elephant seems to have a monocular field of vision equal to 190°. The two eyes embrace simultaneously a space of 313°, of which 67° belong to the binocular field.

In Rodents, the fields of vision extend considerably temple-wards. The Albino Rabbit—with eyes set prominently in the back of the head—seems to possess an anterior binocular field of vision that barely attains 20°, but posteriorly the limits of the two fields of vision touch each other and even over-lap, so that (according to Grossmann and Meyerhausen) there probably exists in this animal a posterior binocular field of vision.

Color perception in vertebrates. Graber has made many experiments to determine this function in animals. In fifty thus examined he found that forty showed a marked preference for certain colors. Only six remained indifferent; among these the Cat, the Guinea-pig, the Rabbit, the Pigeon, the Chicken, the Parrot, and the Tortoise. The Pig prefers green and blue, the Dog blue. Among the birds, three appeared to like blue, two red. The Frog is attracted by red; the Toad detests it. Many of the animals have no marked preference for a certain color; but, in general, light containing many violet, especially ultra-violet rays, seems to produce an agreeable sensation. Those animals that prefer an intense illumination generally like blue. This is the case with some Mammals and Birds, while others prefer red.

According to Graber, it is entirely wrong to say that the chromatic sense in Man is an acquisition due to the progressive perfection of our species, since the Pig and the Dog distinguish blue from red.

The writer has made many experiments with wild and domesticated

Parrots and finds that they are not only much influenced by colors in general, but that their individual chromatic preferences and dislikes are as varied (especially in the larger species of Central and South America) as they are in individuals of the human species.

Experimental researches in the comparative physiology of the visual and color senses by von Hess (*Arch. f. die Ges. Physiologie*, 142), indicates that the visual organs of Fishes show to a considerable extent the capability of adaptation to different intensities of light. After having been in the dark for about 15 minutes their sensitiveness to light was found to be one thousand times greater than immediately after entering the dark from the light. This adaptive change of sensitiveness is brought about partly by a phototropic change of pigment; in a larger part it is independent of it and is physiological.

The composition of the terminal light, i. e., light which strikes the percipient layer of the retina, is altered by the advancement of the pigment in the eye of the fish under the influence of the light, in that the inner pigment absorbs relatively more of the short-waved rays than of the long-waved.

Relatively little of spectral green is absorbed by the advanced pigment, as shown by the fact that fish, gathering at the lightest place of their aquarium, swim to the region of yellowish green or green whether the pigment lies inside or outside.

In experiments with colored baits the fish darted toward the bait, if this differed essentially in color from the ground, but they left it unheeded if it had almost the same color value.

All the facts disclosed by this examination confirmed the opinion of Hess that Fishes are totally color-blind. Hess has also examined the light-sense of photophobic invertebrates, in particular Artemia salina, a Crawfish. Like all Crawfish so far examined, the artemiæ behaved as if their visual qualities were those of a totally color-blind human being.

Hess also records his researches on the *color sense of Birds* according to the principle of the Seebeck-Holmgren test. They exclude the possibility of red-green-blindness in the Chick, and furnish support to his surmise that this animal's visual qualities are similar or equal to those of Man.

The thanks of the Editor (writer of this section) are especially due to J. R. Slonaker and the other officers of the Department of Physiology in Stanford University for their assistance in preparing the material herein set forth under the caption of **Comparative Opththalmology.**

Compass. An instrument for determining direction, as a rule by means of a magnetic needle capable of rotating in a horizontal plane.

Compendil, The. The abbreviated name of the French translation of the great text-book on ophthalmology by Benevenutus Grapheus—a work which stood as the standard on its subject for several hundred years. The full name of the French translation is *"Le Compendil de Bienvenu de Jerusalem pour la Douleur et Maladies des Yeulx."* The name of the Provençal version is *"Las Curas de las enfermetatz et Totas Malautias dels Uelhs."* The title of the Latin original varies, as follows: *"Ars probata de Oculorum Affectibus," "De Oculis corumque ægritudinibus et curis," "Ars Probata de Ægritudinibus Oculorum,"* and *"Practica Oculorum."* The work is generally called, simply, *"The Compendil."*

For the contents of this brief, but epoch-making, book, see **Grapheus, Benevenutus.**—(T. H. S.)

Compensating ocular. An eyepiece specially adapted for use with achromatic objectives, so as to compensate for aberrations outside the axis.

Compensation of errors. In optics, a method of obtaining an approximately correct result by causing one error to neutralize the other.

Compensation, Workman's. Laws concerning, in various lands. See **Legal relations of ophthalmology,** in last third of the section thereof.

Compère-loriot. (F.), n. Hordeolum.

Complementärfarben. (G.) Complementary colors.

Complementary after-images. See **After-images.**

Complementary colors. Any two colors which, when combined, produce white light; each of the two is then said to be complementary, "opposite," "harmonic," or "in contrast" to the other. These colors are: *red* and *blue-green, orange* and *blue, yellow* and *indigo-blue, green-yellow* and *violet, purple* (non-prismatic) and *green.*

Complementary colors can never be perceived at the same time in the same color. If we look at a red object it is possible to see some blue or yellow mixed with it; but we can never say of a color that it is a mixture of red and green.

If red, green, and violet, that is, the three colors most widely separated in the spectrum, are combined in certain proportions, they will produce white. All possible colors therefore may be constructed from a mixture of red, green, and violet: hence these colors are called *primary* or *fundamental* colors. See **Color-sense and color-blindness.**

Complete ophthalmoplegia. Total ophthalmoplegia. These terms are applied to a paresis or paralysis of all the muscles, external or internal, that supply the ocular apparatus. It rarely happens, how-

ever, that no muscle escapes and still rarer is it that the musculature of both eyes are affected in their entirety. External ophthalmoplegia is almost invariably a nuclear palsy and is the result of a lesion affecting the nuclei of the ocular muscles on the floor of the fourth ventricle and in the aqueduct of Sylvius. See, also, **Ophthalmoplegia** and **Muscles, Ocular.**

Complex astigmatism. Astigmatism of both the cornea and the lens in the same eye. When the axis of the corneal and that of the lenticular astigmatism do not coincide, the condition is known as bi-astigmatism. Bi-astigmatism is therefore merely a variety of complex astigmatism. Complex astigmatism should not be confounded with compound astigmatism, on the one hand, or with mixed astigmatism, on the other; for, in both these latter affections, the refraction of the eye is regarded as a whole—i. e., without reference to the seat of the refractional error or errors. In compound astigmatism the meridian of least and the meridian of greatest curvature, possess the same sign (+ or —), while, in mixed astigmatism, the corresponding meridians possess different signs (+ *and* —).

From all the foregoing, it follows that complex astigmatism (when the eye is regarded as a whole, as it has to be for the purpose of fitting lenses) falls into three divisions: (1) Bi-astigmatism. (2) Compound astigmatism. (3) Mixed astigmatism.—(T. H. S.)

Complexus. The entire range of symptoms, phenomena, or signs of a morbid condition.

Complicated cataract. A cataract secondary to or complicated with some other intra-ocular condition or lesion, often inflammatory.

Complications of ophthalmic operations and injuries, Treatment of. See **After-treatment of ophthalmic operations and of their complications.**

Complicirter Staar. (G.) Complicated or secondary cataract.

Compliqué, Adj. (F.) Complicated.

Composé. (F.) A compound body. A compound.

Composition of colors. See **Color-mixture.**

Compound astigmatism. This refractive anomaly is a combination of an axial ametropia with astigmatism of the lens or cornea. See page 656, Vol. 1, of this *Encyclopedia,* also **Refraction and accommodation of the eye.**

Compound color. A color made up of a mixture of two or more primary colors.

Compound eye. Facetted eye. In the head of an insect, the most highly developed of the invertebrates, is sometimes found a pair of lateral, compound eyes or several simple eyes *(ocelli).* In the former

case the cornea is divided into numerous facets, each having its own pigment mass, lenticular cone, and nerve rod. The dragon-fly exhibits 28,000 of these facets. See, also, **Comparative ophthalmology**; and **Insects, Eyes of.**

Compound lens. A combination of two or more lenses.

Compound light. The natural light emanating from luminous bodies is not usually *monochromatic*, i. e., of one color only, but contains in each ray waves of different lengths; hence the term *compound* or *mixed* light.

Compound microscope. A microscope comprising a converging lens or lens-system—the objective—and an ocular, acting as a single microscope.

Compound prism. A number of prisms cemented together.

Compound solution of iodine. See **Iodine.**

Compound spectacles. Spectacles fitted to receive extra colored glasses.

Compress bandage. This is not only one of the oldest forms of eye dressings, but according to Nuel (*System of Diseases of the Eye,* Vol. 4, p. 186) one of the most valuable remedies for infections of the cornea. For the same reason that ulcers of the skin should be covered with a piece of plaster the affected cornea should be protected against the rubbing of the eyelid, and this cannot be better done than by an occlusive bandage. It is therefore necessary to immobilize the eyelids by a well-applied bandage. This can be done so as to exert a certain amount of pressure on them, especially towards the nose, on a level with the tendon of the orbicularis muscle, by a padding made of some elastic material, such as cotton. To render the bandage more absorbent of the tears, conjunctival secretions, etc., a pad of gauze should be placed over the eye, the periorbital hollows being filled in by cotton that is held accurately in place by the bandage. It is not necessary to employ the so-called antiseptic cotton and gauze; scoured cotton is sufficiently aseptic, or it and the gauze can be rendered so by steaming.

Compresses. These are valuable ophthalmic remedies when judiciously used. There is a tendency, however, to apply them too frequently, especially when the patient is permitted to use them at discretion and if definite instructions are not furnished at the time of the prescription. The Editor is in the habit of giving the patient printed directions for the use of *hot* compresses (*cold* applications may be made by substituting ice water), something like the following:

Purchase at a drug store a small package of sterile gauze and a larger one of sterile, layer cotton. Place between two single pieces of gauze a layer of cotton half an inch thick and cut out, with a pair

of sharp scissors, all three layers together, making a pad about the shape and thickness of a man's watch. Put into a basinful of *very hot water* (as hot as the hand will bear it) a couple of saucers.

Now, hold the gauze-and-cotton pad between the thumb and finger and immerse it also in the basin of hot water for a few seconds. Meantime the patient should lie down on his back; the pad should be partly wrung out of the water and placed smoothly and evenly on the (closed) eye to be treated.

Remove one of the hot saucers from the basin; dry it quickly, wrap it in a layer of dry cotton and place it over the eye and the moist pad. These hot applications should be renewed, and applied every two or three minutes (so that they will keep quite hot) for a quarter of an hour.

After making the second application of the hot, moist pad, half a teaspoonful of *the prescribed eyewater* should be slowly poured into the corner of the eye *under the pad.* The lids are to be kept closed, but it does not matter if some of the eyewater runs into the eye.

This form of treatment should be given every .... hours (while the patient is awake) for fifteen minutes at a time.

The patient should not go out into the cold for fifteen minutes after removing a hot compress.

Chlorinated mixtures, well diluted, form common examples of the antiseptic compress and detergent. Buchardt, for example, advises the following mixture: Acid salicylic 0.7; chloral. hydratis 1.5; acid. boric 30.0; sol. aquæ chlorinatæ (1:20) 1000.0.

Alsol is generally used in the form of compresses of 5 per cent. strength; one teaspoonful to a cup of boiled water. It is said to have the advantage over boric acid and sublimate of not causing eczema of the lids when used as a local application. It is, therefore, especially valuable for compresses in blennorrhea neonatorum, in conjunctivitis, granular and scrofular ophthalmias, and in warm solution, in chronic cases; also in hordeolosis, in corneal ulcers and iritis, but in such case in solutions of 1 to 500 and 1 to 1,000. It forms an acid solution with water but is insoluble in alcohol.

Compressor lentis. A portion of the tendinous expansion of the ciliary muscle, inserted into the lens capsules. It is another name for Müller's muscle, and in some of the lower animals is much enlarged and takes a very active part in the accommodation.

Compressor lentis accommodatorius. (L.) The circular equatorial fibres of the ciliary muscle.

Compte-gouttes. (F.) A drop bottle.

Conario-hypophyseal. Relating both to the pineal gland (conarium) and to the hypophysis of the cerebrum.

Conarium. Pineal gland.

Concave. In optics, hollow or depressed in the centre.

Concave-convex lens. A lens with one concave and one convex face, the curvature of the latter being the greater.

Concave cylindric lens. A lens having one concave cylindric surface and the other plane. Also called a *plano-concave cylindric lens.*

Concave grating. In optics, a concave mirror of polished speculum metal ruled with lines which lie in parallel equidistant planes. See **Diffraction.**

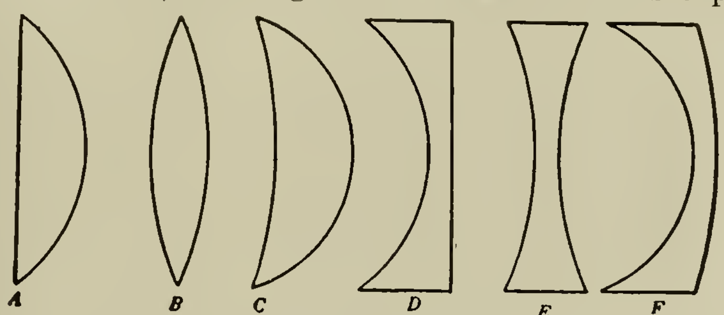
Concave lens. A lens having one or both surfaces concave, and proportioned so as to produce a lens that is thinnest in the center. See **Lens,** also **Ophthalmic lenses and prisms.**

Concave mirror. In optics, a concave surface of polished glass or other suitable substance that forms images by the reflection of rays of light.

A mirror of this quality converges parallel rays of light to its principal focus, and thus forms an inverted, though real, image in front of the mirror. The principal focus of a concave mirror is equal to one-half the length of its radius of curvature, $F = \frac{r}{2}$. The chief ophthalmic use of the concave mirror is in the *ophthalmoscope* and *skiascope.*

Concavo-concave. Biconcave. A glass or lens concave on both sides.

Concavo-convex. In optics, applied to a lens, concave on one side and convex on the other, meaning that its *concave* side is exposed to the



Types of Various Lenses.

(a) *Plano-convex:* One side convex, the other plane. (b) *Double convex:* Both sides convex. When both sides are equally convex, as represented in the figure, the lens is called biconvex. (c) *Concavo-convex:* One side concave, the other more convex. (d) *Plano-concave:* One side concave, the other plane. (e) *Double-concave:* Both sides concave. When they are equally concave, as in the figure, the lens is called biconcave. (f) *Convexo-concave:* One side convex, the other more concave. Either c or f is called a *meniscus,* or periscopic lens. (Norris and Oliver.)

incident light. The lens may be either one of two forms: convex, thickest in the center, a *meniscus;* or concave, thinnest in the center, a *contra-meniscus.* See **Ophthalmic lenses and prisms,** also **Lens.**

Concavo-plane. In optics, applied to a plano-concave lens to indicate that its concave side is exposed to the incident light. See **Ophthalmic lenses and prisms,** also **Lens.**

Concentric. Having a common centre.

Concomitant squint. CONCOMITANT STRABISMUS. COMITANT SQUINT. In comitant or concomitant squint—as the adjectives imply—the non-fixing eye generally follows or accompanies all the movements or excursion of the fellow organ. In other deviations—paralytic squint for example—there is a limitation of these excursions, so that the deflected eye does not necessarily accompany the ocular movements of the other eye. See **Muscles, Ocular.**

Concremente des Auges. (G.) Ocular concretions.

Concretions. See **Colloid bodies.**

Concretions, Conjunctival. These are seen as small, yellow granules or minute elevations on the conjunctiva of the lids and transitional folds. They occur not only in eyes suffering from chronic inflammation of the conjunctiva—where they are difficult to see—but they may be found in apparently normal conjunctiva. Often they are surrounded by a small, red, injected area. They are generally discrete but are sometimes seen united in groups or in rows. The smallest spots are grayer and can be recognized only with a magnifying lens. The granules are formed in normal or in newly-developed glands of the conjunctiva, either as morbid excretions of the glandular epithelium or as a degeneration of this epithelium with further metamorphosis of the detritus. Occasionally they are true *hyaline* or *colloid* bodies; also they may or may not be associated with infarcts of the Meibomian gland, or lithiasis of the true conjunctival glands. The best treatment of them is removal with a spud. See, also, **Concretions, Ocular**; and **Colloid bodies.**

Concretions, Ocular. These solid deposits may occur as degenerations, or new formations, in various parts of the eye—notably in the conjunctiva and in the canaliculi. As Parsons (*Pathology of the Eye,* Vol. 1, p. 93) points out, they are of frequent occurrence in the conjunctivæ of elderly people, in the lower fornix and less frequently in the tarsal conjunctiva. They appear, either by the naked eye or with a loupe, as white or yellow specks arranged in horizontal rows or in groups. They are often expressed by slight manipulation; in other cases they are more deeply set. They are the products of degeneration of cells and mucoid exudate in the lumen of minute cysts. The

cysts are retention cysts of glands of new formation, due to irritation, and also of the so-called Henle's glands. They are surrounded by an area of lymphocytic infiltration. Their walls consist usually of a double layer of epithelium, the inner layer being cubical or cylindrical, with numerous goblet-cells. The epithelium is usually intact, but may be flattened by the pressure of the concretions, or absent in places from atrophy, or thickened by proliferation. Some of the cells are swollen and degenerated, others are cast off into the lumen and help to form the basis of the concretions (Wintersteiner). They, however, play a relatively small part, and their co-operation could not be proved by Fuchs. Both authors agree in their descriptions of the concretions, and their conclusions can easily be confirmed by anyone. Each space contains one to five concretions—usually one only,—but all are built up by aggregation. They are usually hyaline, with faint or well-marked lamination, best seen at the periphery, though many have radial striations here. Like all these degeneration products, they stain variously according to their chemical constitution. They stain very well with safranin (Wintersteiner), red with eosin, peripherally or in zones with hematoxylin, variably with fuchsin, not at all with carmin, yellow with van Giesen, violet in parts with Gram, not at all by Löffler's methylene blue, red with orseille. They do not contain calcium carbonate or phosphate, give no xanthoproteic, murexide, or amyloid reactions (Fuchs). They are stained blue by thionin, faint brown or violet with vesuvin, faint violet with mucicarmin. They do not, therefore, give mucin reactions. They belong to that indeterminate quantity—v. Recklinghausen's hyalin. Both dyes and culture experiments fail to show the presence of bacteria, actinomyces, or botryomyces (Fuchs). Besides a variable amount of inflammatory infiltration in the connective tissue, with occasional mast-cells and nodules of brown pigment, small hyaline globules are often present, as in other conditions, e. g. trachoma. They are not of any pathogenic importance. The stages in the formation of these hyaline bodies have been exhaustively worked out by Fuchs. Numerous polymorphonuclear leucocytes infiltrate the epithelium, and are present, usually much degenerated, in the lumen. Their nuclei often form branching filaments with nodular enlargements amongst the cells, similar to those described by Peters in conjunctivitis. Many lumina are empty; others contain homogeneous or finely granular lumps or networks. Mono- or polymorpho nuclear cells, or both, are often present, usually bereft of a definite cell body. They are also found in cystic spaces in the epithelium, frequently sickle-shaped with a cell body. Nuclear fragments and clumps occur. Swollen epithelial cells are found in the walls and free in

the lumen; the latter swell into granular masses and their nuclei degenerate, or they stain deeply with eosin and retain their nuclei (Wintersteiner). The smallest concretions seem to be swollen nuclei (Fuchs); these fuse, showing larger bodies with crenate edges. Laminated concretions are found embedded in deeply staining nuclei. Larger, more faintly staining ones with indications of a nucleus are seen. These are probably of epithelial origin. Others fuse into complex, tubularly arranged masses, each tubule having a darker, radially striated cortex. Increase in density occurs both at the periphery and in the nucleus in different cases, and in this manner laminæ may be laid down resembling a renal calculus. The concretions may grow out of the mouth of the gland and project from the surface, or the mouth may be closed by a mass of cells. The smaller bodies are often surrounded by a homogeneous layer of mucoid substance, but in no case do these mucoid deposits give true mucin reactions. In some cases there is a membranous covering, which spans the crenations, and is best seen when raised from the concretion near the mouth of the gland. It resembles an endothelial membrane, and is in places definitely cellular. Concretions with radial striations of the periphery much resemble actinomyces, and were erroneously described as such by de Vincentiis in one case, and by Fuchs in his earlier communication to the Ophthalmological Society at Heidelberg. This has been disproved by Fuchs' later researches and by Wintersteiner. Faber published a case as botryomycosis, similar to the condition found in horses, but this is also probably a mistake. Antonelli found hyaline concretions in cysts of Krause's glands; in this case he was able to trace the development from blood-clot. Wintersteiner described laminated concretions, exactly similar to the ordinary conjunctival ones, in cysts of Krause's gland; the presence of typical foreign-body giant-cells was peculiar to this case, but might well occur in all cases, and, indeed, indications of their formation are not wanting. Mitvalski reported similar "colloid pearls" of the Meibomian glands. See, also, **Colloid bodies**; and **Concretions, Conjunctival.**

Concretio palpebrarum cum bulbo oculi. (L.) Symblepharon.

Concussion cataract. A cataract produced by concussion, as from an explosion. See Vol. II, page 1470 of this *Encyclopedia.*

Concussion of the retina. See **Commotio retinæ.**

Condensateur. (F.) Condenser.

Condenser. In optics, two plano-convex lenses with their convex surfaces in contact, used in a projecting apparatus to deflect the more divergent rays from the light source so as to fall on the focussing

lens and ultimately on the screen to amplify illumination. Also, see **Condensing lens.** In electro-physics, an electrical accumulator.

Condenser-hygrometer. A dew-point hygrometer.

Condensing diaphragm. A cylindrical diaphragm, to which are adjusted a series of either converging or diverging lenses.

Condensing lens. A convex lens or a combination of lenses used to concentrate a strong light upon some object or surface. Also called a *condenser.*

This means of illuminating the anterior segment of the eye and for other ophthalmic purposes is found in many forms. Generally they consist of a glass to be used monocularly; often they appear as binoculars. Both varieties are described under several captions in this *Encyclopedia.* A few types are figured on the following page.

Condiloma dell'iride. (It.) Gumma of the iris.

Conduit nasal. (F.) The nasal duct.

Conduits lacrymaux. (F.) The lachrymal ducts.

Condyloma iridis. (L.) Gumma of the iris.

Condyloma of the iris. (Obsolete.) Condylomatous iritis; iritis gummosa; gumma of the iris.

Condy's fluid. A proprietary disinfecting solution of unknown composition; said to be prepared from various permanganates.

Cône. (F.) Conus.

Cone body. The inner segment of a retinal cone.

Cône de lumière. (F.) Cone of rays.

Cone fibres. The prolongations towards the sclera of the retinal cones. They enlarge to form the cone granules, and terminate, in pyramidal bases, upon the surface of the outer molecular layer of the retina, from the edges of which are given off fine processes. See **Histology of the eye.**

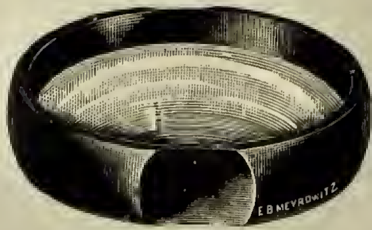
Cone-foot. See **Cone-granules.**

Cone-granules. These histological elements of the retina are found in the outer nuclear layer. They are connected with the cones externally and internally by a thick process which, known as the cone-foot, becomes bulbous. They terminate in fine fibres in the outer molecular layer. See **Histology of the eye.**

Conéine. (F.) Coniine.

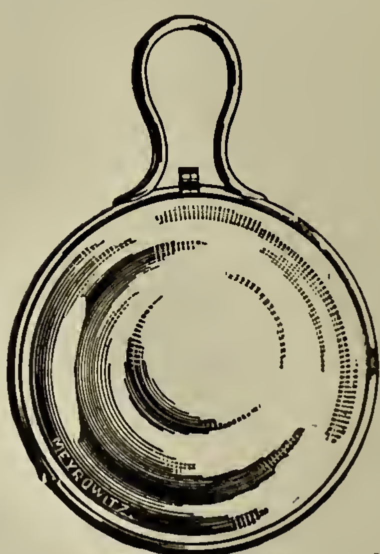
Cone of rays. All the rays which, originating from a given point, fall on a given flat surface.

Conephrin. A trade name given to one of the numerous combinations of cocain and suprarenal extract to be used locally or by hypodermic injection in operations on the anterior part of the eyeball. The ingredients are present in practically the same proportion as in codrenine.



Condensing Lens with Hard Rubber Protecting Ring.

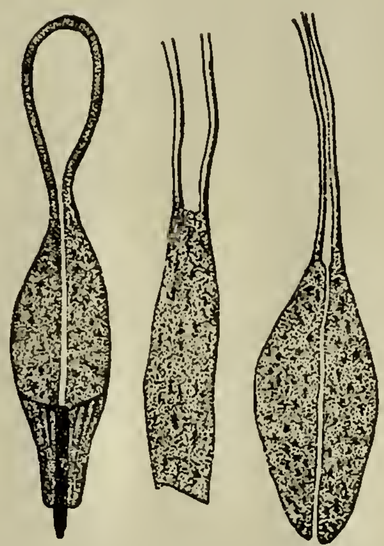
Condensing Lens Attached to a Head Band.



Binocular Condensing Lens. Condensing Lens with Metal Rim and Handle.

Cone rod. The outer segment of a retinal cone.

Cones, Double. Peculiar modifications of the cone-cells of the retina are sometimes observed, in which two of these elements are connected, producing the double or "twin cones" first described by Hannover. The more usual form of union is fusion of the bases or inner segments, but Hannover and others have described looped connections between the outer segments, the observations of Norris and Wallace having been made upon the human retina. Norris accepts the view that "the external extremities of the cones and rods are loops, the outer



Diagrammatic View of Twin Cones. (Hannover.)

member of a cone bending over to become continuous with the outer member of an adjacent rod, or less frequently with the outer member of another cone (twin cones). Adjacent rods unite also by their curved outer segments, ending thus also in peripheral loops. The outer member of a cone, having thus curved on itself, runs down along the side of the inner segment as a cylinder having about the same calibre as at the turn, and, after perforating the external limiting membrane, passes alongside of the nucleus at the base of the cone, and may be followed for some distance in a tortuous course between the nuclei of the so-called outer nuclear layer, anastomosing, at times, with some of the other nerve-fibrils of this layer.—(*System of Diseases of the Eye,* Vol. I, p. 301-2.)

Cones of the retina. The cones are flask-form structures, likewise possessing a thinner outer and a thicker inner member. The outer member is narrowed conically toward the apex, the inner member

bays out, yet the form and dimensions of the cones vary a great deal with their location. The longest and slenderest cones are found in the center of fovea, for their inner member is only 2.5μ thick. These foveal cones look more like rods than they do like the other cones, but their cone nature is made clear by the absence of visual purple. The extrafoveal cones decrease in length toward the periphery, particularly in the outer member, which is reduced to a miniature cone of 6 mm length at the ora serrata. The inner member is some 3μ shorter than the neighboring inner members of the rods and takes on a more and more bellied form toward the periphery (up to a diameter of 7.5 mm according to Greeff). With respect to the finer structure there is great similarity between rods and cones; both show the same constituents. The thread apparatus is especially well developed in the cones; it consists of a thick fiber mesh and occupies two-thirds of the inner member. The cones contain no visual purple. The distribution of the rods and the cones and their relations to each other are best studied in surface preparations of the retina—in which the thicker cones appear as larger discs, the thinner rods as smaller discs. In the center of the fovea is a district containing only cones; it has a diameter of about 0.5 mm.—according to Fritsch, only 0.15 mm. But the very slender cones are found only in the middle of this district and in irregular arrangement; toward the border of this field the cones are notably thicker and are arranged in oblique rows; a beautiful drawing of the cone-mosaic of the fovea has been published by Heine. Outside this field the rods appear; at first they are strewn about among the cones; soon, however, they become united into a simple circle about each cone. Farther on the rods become more and more numerous and the cones wider apart until some three to four circles of rods intervene between two cones. This distribution is attained some 4 to 5 mm. away from the center of the fovea and is then maintained quite constantly to the periphery. In the most extreme periphery the cones are again relatively increased.—(Salzmann-Brown.) See **Histology of the eye.**

Cônes retiniens. (F.) Retinal cones.

Cone style. The outer segment of a retinal cone.

Confocal. Having the same foci; said of two or more lenses.

Confusion colors. See **Confusion tests**; and **Color-sense and color-blindness.**

Confusion tests. Although Holmgren's wool test for color-blindness depends upon confusing the color-blind person by means of various color shades, yet Burch (*Physiological Optics*, p. 139) has not included it in his confusion tests for color-blindness. He thus describes a

number of tests, including his own: *Nagel's*—A series of cards, each bearing a ring of spots the size of peas, of various shades of pale red, green, brown, crimson or purple arranged so as to confuse the color-blind. Full directions are given with each set of cards, which should be kept away from the light when not in use. *Stilling's*—A series of cards covered with irregularly-shaped spots in colors likely to be confused. Thus for red-blindness a number or date is written in red spots and the space filled in with spots of green or brown, and still further to confuse the eye, a number of false trails are led in all directions in spots slightly darker than the rest. Similar cards in different colors are employed for other varieties of color-blindness. Thus, for instance, the green-blind confuse various shades of green and purple. Some of the designs are difficult to trace, even to the normal sighted. These are used for the detection of cases of slight color-blindness. *Burch's*—This consists of a set of cards painted in colors which appeared exactly alike to the late Lt.-Col. W. R. L. Scott, who was red-blind. Thus vermilion is matched by green the color of a year-old ivy leaf. On the green half of the card are painted the words DONT GO, the letters NT being in vermilion and the rest in blue. He could see the blue but not the red, save by holding the card sideways so that the light fell on the brush marks. To render these invisible a sheet of perforated zinc is fixed some six inches above the card, and the observer looks through a tube containing a convex lens of eight diopters focused on the zinc. The card is so far beyond the focal plane that all brush marks are invisible, and given the colors any design can be painted in a few minutes. The other cards are geranium red, matched with a French grey or bluish slate-color; emerald green, matched with a rich ochre made largely with mars yellow; and lilac, made with mauve, magenta, and white, matched with a pure blue. The red-blind are unable to see geranium-red letters against French grey, or yellow ochre letters against green. But they instantly perceive salmon-pink against green, though the difference to normal eyes is very slight. They cannot distinguish blue letters on a lilac ground, but they can easily see letters of a slightly paler blue upon the blue itself, although not one in twenty with normal sight can do so. Green-blind people can see the lettering on all the cards save the last, the blue and lilac appearing alike to them. *Ryland's*—This confusion test consists of a pair of disks of ordinary green glass which appear of a darker green when superposed, and a second pair of special kind, each of which singly is green, but the two when superposed look red. The explanation is that certain films and liquids which are partly transparent to green

are extremely transparent to a narrow band in the red. Thus in thin layers the green transmitted overpowers the red, but in thicker layers so much of the green is stopped that the red asserts itself. Now although the red-blind man is as likely as not to say that the two disks when superposed look red, he will say the same also of the disks of ordinary green, for to him dark-green and bright-red are alike. But the normal sighted can generally be recognized by their surprise at the change if they have not seen it before. It is necessary to suit the light to the particular disks employed. For some, a candle will answer, for others an incandescent gas-lamp. Some will work by daylight—others do best with a glow-lamp. Cobalt glass looks blue when of moderate thickness, but a glow-lamp seen through a thick piece appears red. Permanganate of potash on the contrary is pink in weak solutions and deep violet in strong ones. See, also, **Color-sense and color-blindness.**

Congeneric. In optics, applied to lenses of the same character; thus, for instance, two convex lenses are said to be *congeneric lenses.*

Congenital abnormalities. See **Congenital anomalies.**

Congenital anomalies of the eye. CONGENITAL MALFORMATIONS OF THE EYE. The inexplicable and unknown have ever had a charm for theorists, and a search for a satisfactory explanation of congenital defects has been productive of many hypotheses. In the study of congenital anomalies of the eyes, it cannot be said that any of the many theories brought forward can be accepted as final. One will be quite satisfactory in the explanation of a certain kind of anomaly which will fail to explain another kind. The true explanation probably resides in the fact that there are many factors at work, any one of which may be responsible for several kinds of anomalies, or a given anomaly may not always be the result of one given factor but of various factors. Some one has truly said that "In the field of conjecture all men are equal whose powers and opportunities for observation are equal." Everything ranging from speculation to fact has been brought forward in explanation of anomalies of structure.

All eye anomalies are rare (taking into consideration the total number of eyes), some being relatively more rare than others. It is not vouchsafed to any one man to have the opportunity of studying all the anomalies at first hand either clinically or microscopically. Especially is the dearth of microscopical material noticeable, so that oftentimes a theory will be offered in explanation of a given anomaly based upon the microscopical findings of but one or a few cases. It is conceivable how an honest but wrong conclusion may thus be drawn therefrom. The same remark applies to experimental researches along the

lines of deformities. The breeding of artificially deformed animals or even of somewhat anomalous ones, the effects of temperature, chemicals and feeding upon the resultant offspring may give results, but to accept these results as final and to apply them as explanatory of human anomalies is perhaps a little far-fetched. The influence of temperature, drugs, chemicals and disease have been utilized in the attempt to unravel some of the mysteries of defects. These are general influences and must of necessity affect the organism as a whole, yet one organ, especially a highly-specialized one—such as the eye—may be more profoundly affected than others less highly organized. Still it is difficult to conceive of the eye alone suffering as a result of the extraneous and common influences, while the rest of the complex organism being entirely normal in its development and free from defect. The question here probably resolves itself into one of nutrition. The more elaborately differentiated a tissue, the more susceptible it is to nutritional disturbances. It may be that the ocular tissues in the development of their nutrition are disturbed either by an excess or diminution, so that the resultant effect is an anomaly. The normal development of the eye in its various parts is so exquisitely timed and ordered that a hesitancy at one point, or the persistence past its allotted time of a temporary fetal structure at another point, may so unbalance the normal procedure that a recognizable defect is produced in the completed eye.

Theories to explain ocular anomalies fall underneath two chief heads, viz., developmental and inflammatory. Under the developmental head may be subdivisions as follows: 1. Lack or absence of development (aplasia). 2. Arrested development. 3. Mal-development. It is conceivable, and in reality occurs, that the optic vesicle fails to bud off from the thalamencephalon and the condition of anophthalmia results. In other cases the failure of local nutrition or the persistence of a fœtal structure may so blight one of the ocular structures that an arrest of development ensues. Under mal-development may be included those anomalous conditions where there is a failure of proper differentiation of tissues. Intra-uterine inflammation has had, and still has, its advocates. It fits in nicely in the explanation of a few anomalies while failing utterly to explain others. Its general application, as by Deutschmann stating that all congenital defects are due to inflammatory processes, is unquestionably an extreme view. On the other hand, the absolute exclusion of intra-uterine inflammation as a causative factor is likewise extreme. Those writers, like Parsons and others, who invoke the theory of inflammation only when developmental causes fail to explain satisfactorily,

are no doubt correct and are taking the logical stand. One must avoid, in making observations, to attribute as a sequence that which is merely coincidental. Such an example is furnished by the observation of coloboma of the iris in two children of a woman who had had an iridectomy done four years previous to marriage. (Tobias.) Hertwig's experiments in delaying the development of the medullary ridges of frog embryos with 0.6 per cent. salt solution, and Brown-Séquard's observation of corneal and lenticular opacities in the progeny of guinea pigs, whose restiform bodies were divided, while not coming exactly under the foregoing criticism are not in any way conclusive as bearing directly on the lesions found.

The great tendency to confuse post-natal findings with ante-natal findings is no doubt a prolific source of error in arriving at conclusions as to the actual etiologic factors causing a defect in a child brought some time after birth to the ophthalmologist for observation. Of prime importance are those intra-ocular conditions which are not found until months or even years after birth but which are described as congenital. A gross external defect immediately arouses attention and comes therefore early to the notice of the ophthalmologist. We have but to keep in mind certain forms of cataract, corneal opacities and certain choroidal changes. The so-called macular coloboma is one of the conditions in dispute. A satisfactory developmental defect explanation has not been furnished for it. We know that the macula does not lie in the line of the fœtal cleft, as was once held but which is now thoroughly discredited. Also it is manifestly too speculative to invoke an accessory cleft in the line of the macula to explain this type of coloboma. It would seem that inflammation best explains it.

This brings up the question as to just what constitutes fœtal inflammation. A true inflammatory process in the ordinary acceptance of the term, presupposes an intact and complete vascular system. The fœtal vascular arrangement differs materially from that of post-natal life so it would appear that fœtal inflammation is a term used rather loosely and without a knowledge as to exactly what it is. Towards the end of fœtal life it is conceivable that inflammatory processes might take place intra-ocularly analogous to those of post-natal life. But in early fœtal life this is hardly so. It is likewise very probable that many cases reported as congenital were in reality post-natal conditions.

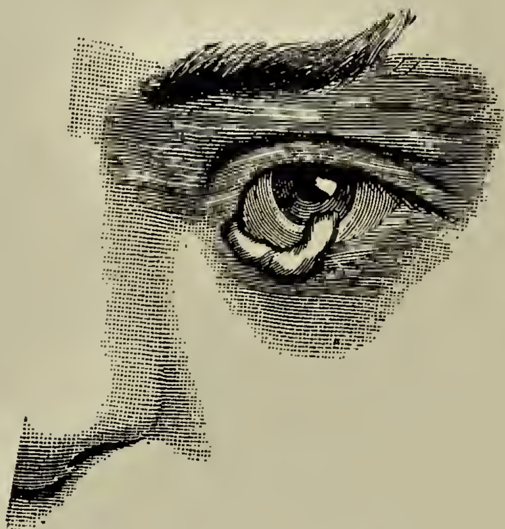
Parsons states that heredity is comparatively rare in association with congenital defects. The literature of recent years, however, proves that more and more evidence is being adduced to show the weighty influence heredity exercises. Further on more will be said

in this connection. Inherent defect in the germ is inseparably bound up with the question of heredity, or the ability to transmit to succeeding generations traits, characteristics and defects. The potential possibilities of the germ are something beyond the conception of the human mind. How and by what force the original cell is eventually differentiated into the various and complex tissues of the human body with exquisite nicety and precision in the normal individual is inexplicable. The transmission of a solitary defect is even more so. If it is permissible to speak of certain tendencies to disease as congenital, quite an imposing array might be mentioned. They may be the result of some purely anatomical defect or an hereditary tendency. Keratoconus while usually occurring in adolescents or young adults probably has its anatomical basis in a weak and centrally thinned cornea. Small eyes with relatively large lenses have the pre-requisites for a future glaucoma. Optic atrophy, retinitis pigmentosa, certain types of cataract, degenerations of the cornea and even gliomata, manifest an hereditary tendency and, occurring as a rule early in life, lead one to suspect that the underlying conditions were present, if latent, at birth. To pressure of the amnion and to amniotic bands have been attributed some of the external defects, such as symblepharon, corneal opacities and colobomata of the lids. Some writers, among them Van Duyse, attribute a very important rôle to pressure of amniotic bands. However, to explain the occurrence of corectopia, coloboma of the iris, aniridia, coloboma and dislocation of the lens to amniotic bands is giving this possible etiologic factor an importance to which it is not justly entitled. The supposition that pressure exerted from the ventricles through the optic stalk to the eye, is the cause of various malformations, is hardly tenable. This would have to occur early in fœtal life as it is known that the eye up to the third month lies outside of the orbit and is well protected from undue pressure from behind.

Eye defects, often multiple, are frequently found in conjunction with other bodily defects. Gross defects of the brain ranging from aplasia of various parts to anencephaly occur though they are probably concomitant conditions and all due to the same cause. Among the defects may be mentioned microcephalia, hare-lip, cleft-palate, syndactylism, spina bifida and defects of the genitalia.

The subjects of cyclopia are usually very much malformed and die early. The eyes more or less completely fused together show, as a rule, multiple and gross defects, coloboma of the fundus being a common accompaniment. The earlier inhibition of development occurs, the more marked are the defects. Thus we find frequently associated in the single individual multiple defects. As an illustration, we com-

monly find colobomata of the iris, ciliary body, retina, nerve and choroid together. Microphthalmia and orbital cysts occur very frequently associated. The most pronounced grades of microphthalmia are usually clinically diagnosticated as anophthalmia. An otherwise well-formed and intact eyeball, which is but smaller than normal, has been given the name of nanophthalmia. Persistent hyaloid artery, while occurring alone, is also found in conjunction with other defects. Cryptophthalmia is always associated with a badly disorganized eye, the greater part of the cornea being usually indistinguishable as clear cornea. It is in this condition that a complete symblepharon occurs, otherwise a congenital symblepharon is exceedingly rare.



Incomplete Coloboma of the Left Lower Lid. (Van Duyse.)

Lid colobomata credited to pressure of amniotic bands and epibulbar dermoids, due to epithelial inclusions, occur with bulbar colobomata and microphthalmia, but as regards the latter two it is questionable if they are also caused by amniotic bands. Some references have been made in writings to an atavistic tendency of the organism as explanatory of some defects, but this has never received much recognition. In some of the lower animals certain conditions are found which are normal for the animal, but which constitute defects when found in man. For instance, the hyaloid artery persists in the ox, ectropion uveæ is as normal to the horse as are medullated nerve fibres to rabbits, and coloboma of the iris to cochinchina fowls.

As the scene of greatest and most complicated fœtal activity is at the cleft, we naturally expect the largest number of pathological findings there and in this we are not disappointed. The numerous defects in this situation are relatively so frequent that the term typical is

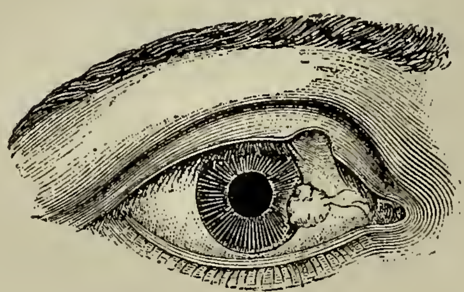
applied to them. Similar defects in other situations are therefore termed atypical. The late closure of the fœtal cleft, or the persistence of mesoblastic remains in the cleft, have been the basis of most theories in explanation of congenital defects. While the theories with such a basis prove quite satisfactory, in the typical defects, they fail utterly to explain atypical cases. It was at one time held that the fovea was formed in the fœtal cleft, also that the cleft in the beginning did not occupy the normal position of a later stage, viz., downward and slightly inwards, but that it underwent a subsequent rotation. This view has been completely abandoned. Fœtal syphilis by affecting nutrition may provoke changes classed as anomalies, yet a luetic offspring has perfectly normal eyes and it is fair to assume that a developmental defect may be present coincidental with syphilis and yet in no way dependent

Coloboma of the Upper Lid, with Dermoid. (Talko.)

upon it. Among those conditions classed as congenital which are of post-natal development are medullated nerve fibres. As Fuchs states, the optic nerve fibres at birth possess no medullary sheath so that medullated retinal fibres cannot be congenital. Corneal defects, especially opacities, are likewise confused. A corneal staphyloma present and noticed a few days after birth of course cannot be of post-natal origin and it probably represents the strongest evidence of a congenital defect, the result of intra-uterine inflammation. Ophthalmia neonatorum may produce opacities which later in life are referred to by the laity as congenital and must be excluded in properly designating those opacities which are of true ante-natal origin. Quite a number of cases of gonorrhœal ophthalmia present at birth are on record. Of interest is Nieden's case, in which the fœtus was born with the fœtal membranes intact. In such cases it must be admitted that infection takes place through the fœtal envelope from a previous diseased endometrium. It is not necessary that the mother suffer a general infection if the possibility of exogenous infection be admitted. Leber and Addario observed in the third covering of a goat, the two previous ones having resulted disastrously, that the resulting offspring suffered with a congenital panophthalmitis. From the vitreous was

obtained a bacillus having the morphological characteristics of the diphtheria bacillus.

One of the much disputed conditions is that of congenital anterior staphyloma. Two theories chiefly have been brought forward to explain it. An early theory was that anterior staphyloma was the result of a non-differentiation of the cornea, in consequence of which the intra-ocular pressure was sufficient to cause it to yield and stretch. Of late years Treacher Collins has revived this theory. The other theory is that the condition is a result of an intra-uterine inflammatory process with ulceration and perforation of the cornea with a resultant staphyloma formed in much the same way as it is in post-natal life. Both theories have great obstacles to explain away. A consideration of the inflammatory or ulcerative theory brings up the question of infection of



Coloboma of the Lid with Dermoid at Internal Angle. (After de Wecker.)

the fœtus and the route it travels. Roughly we may divide the route of infection into endogenous and exogenous. Both are circuitous and possessed of many steps. The endogenous presupposes the passage of an infecting organism through the mother's blood to the placenta, through some breach of continuity in the placenta into the fœtal blood and thence to the eye. It has been shown that the cornea is avascular during its development, therefore infection endogenously cannot reach it directly. Seefelder holds that corneal opacities are the result of an anterior uveitis. Whatever inflammatory process is sufficient to cause resulting corneal scars will, if carried to a more advanced stage, result in a perforation of the cornea. Therefore, if we admit Seefelder's contention as to the formation of corneal opacities, we can also apply the same explanation to the causation of anterior staphyloma. Admitting that endogenous infection occurs, then there is in the circulation of the fœtus an infective agent capable of setting up inflammatory and ulcerative processes in the eye. That the rest of the fœtal organism should escape all deleterious results and that a selective action should be shown for the ocular tissues would be exceedingly strange. The exogenous theory explains infection of the amniotic fluid either by

way of the maternal circulation to the placenta and then through some defect in the placenta to the amniotic fluid, or by direct infection from the endometrium through the stomata of the fœtal membranes to the amniotic fluid. The amniotic fluid has been observed many times infected and even in a putrid condition, but it does not follow that the eyes were necessarily involved. From the fourth month of fœtal life till shortly before birth the lids are sealed together by an epithelial union which effectually protects the eyes from extraneous influences. So if an exogenous infection occurs there must be a hiatus in the epithelial connection allowing communication between the conjunctival sac and the amniotic cavity. The fact that corneal defects are usually bilateral would speak in favor of the exogenous theory. Trauma either from the fœtus itself or from the outside can hardly be reckoned as provocative of corneal or lid defects. Panophthalmitis may result from a perforating corneal ulcer if we grant the possibility of intra-uterine corneal perforation, just as it does in later life and the condition go on to phthisis bulbi, or even complete destruction of the globe. Some observers look upon microphthalmia as caused in this manner. Many infectious diseases are transmitted to the fœtus, usually affecting the fœtus profoundly. Among those organisms known to occur are the pneumococcus, staphylo- and streptococcus, and those of glanders, tuberculosis and anthrax. Variola, no doubt a germ disease, is likewise transmitted. Much attention has been directed to the gonococcus as a possible etiologic factor, but from those cases observed the child was no doubt infected during its passage through the birth canal. It cannot be accepted that the gonococcus is the cause of congenital corneal staphyloma, as the time intervening between the possible infection and the birth of the child is too short to allow of its formation. Furthermore with staphyloma the lids are frequently found absolutely free of inflammation.

To heredity, and through it the acquisition by the germ cell of an inherently defective constitution, must be accorded considerable importance. A tendency may be transmitted or the defect or disease itself. By true heredity we mean the direct transmission of a disease or defect. Where succeeding generations are affected without skipping, it is spoken of as direct heredity, and where one or more generations are skipped it is called indirect heredity. One peculiarity of certain hereditary diseases is that they remain latent in the female and are transmitted through the female but show themselves in the male offspring. Hereditary tendencies show themselves in certain forms of optic neuritis, retinitis pigmentosa and various forms of cataract. The child is not born with the actual defect but the tendency

is there and is congenital. In certain of the congenital defects direct heredity can be excluded, viz., cyclopia and anophthalmia, as these individuals die as a rule early and have no offspring. Von Hippel does not accord to heredity much importance in microphthalmia and colobomata. Aniridia and ptosis are striking examples in which heredity plays an important rôle. Collateral heredity where the disease or defect is not found in the parents or near relatives of the same generation, with the possible exception of cousins, is frequently associated with consanguinity. Consanguineous marriages of healthy people will not produce detrimental results but doubtless do accentuate a family taint, whereas an admixture of a healthy outside blood will so dilute the taint that in future generations the likelihood of it cropping out is minimized. If this were not so most of us would be affected, for if we but go back far enough we can no doubt find a tainted ancestor. In albinism La Gleyze comes to the conclusion that consanguinity is more of a factor than heredity. Loeb, in a very extensive and pains taking study of hereditary blindness, tabulated quite a number of congenital conditions where heredity was manifest. Whereas in the past heredity has been considered a negligible factor in malformations, it appears now that the pendulum of opinion is swinging rather too far in the opposite direction, and according to heredity too important an influence. Large numbers of cases are required to formulate a positive opinion and large numbers of many of the defects do not occur. Furthermore, the observations are scattered and statements of the patients themselves are taken as regards the occurrence of similar defects in their parents, grand-parents and relatives, which cannot always be verified by the reporter. Direct heredity is a striking feature in aniridia, though the transmitted defect may not be identical in kind or degree. For instance, an aniridic father may have a son with a coloboma of the iris. Collateral heredity is manifested in microphthalmia according to the figures of Pflugk and Komoto. The figures taken from Loeb in regard to ectopia lentis shows a very high percentage due to direct heredity. A. R. Gunn reported seventeen of twenty-two children with congenital dislocation of the lens where no colobomata of the uveal tract were present. These occurred in five families where but one parent in each family was affected.

Blue sclerotics have been followed and described by Adair-Dighton, Stephenson, Rolleston and Harman. It would seem from these English writers that blue sclerotics are fairly common in England. The heredity in this condition is quite marked. A frequent accompaniment of blue sclerotics is osteoporosis evidenced by frequent fractures. A weakness of the tunics of the eye manifesting itself later by the

development of high myopia may have both a hereditary and a congenital basis. In a family observed by the writer consisting of father, mother and five children, all had high myopia and three of the children cataract. Reference has been made before to the question of transmissibility of acquired defects. Tobias' observation is brought to mind. A mother on whom a bilateral iridectomy was done four years previous to marriage, one being up and in the other down and in, gave birth to two children with colobomata of the iris and choroid downwards. Three older children were normal. This case is cited as an example of coincidence as it cannot be presumed that there was any real relationship.

Without a knowledge of at least the main elements of embryologic development, one can hardly appreciate the study of congenital anomalies. While the subject will be treated in extenso in another part of this *Encyclopedia,* a brief review is not considered here out of place. The first appearance of the eye consists in the protrusion or evagination from the medullary wall of the thalamencephalon of a vesicle known as the primary ocular vesicle. This protrusion or pouch remains in connection with the cerebral vesicle. This connection, which at first is broad, becomes narrowed as development proceeds and ultimately forms the optic nerve. The primitive ocular vesicle is at first a cavity communicating through its pedicle with the general cavity of the cerebral vesicle. It is covered externally as it develops forward by the epidermic layer of the epiblast. Where these two layers meet there is developed upon the ectoderm a thickening which, increasing gradually, pushes the ocular vesicle backwards, inverting it and almost completely obliterating the original cavity of the ocular vesicle and thus a cup-shaped hollow is formed which is termed the ocular cup, or secondary vesicle. Into this is received the intruding thickening of the ectoderm, the involuted epiblast layer which is the rudiment of the lens. As the involution of the epiblastic layer takes place it forms a pouch which finally becomes shut in in front, thus forming a closed sac called the lens vesicle. The ocular cup consists therefore of two layers, the outer of which, originally the posterior half of the primitive ocular vesicle, becomes thin and is destined to form the pigment layer of the retina. The anterior half of the primitive vesicle which, when invaginated, forms the inner layer of the ocular cup, becomes much thicker and eventually is developed into the nervous layers of the retina. The two layers are continuous with each other at the margin of the cup. The retina therefore can be considered as an isolated portion of the brain itself. Between the two layers of the ocular cup are the remains of the cavity of the original primary vesicle which is eventually oblit-

erated by the union of the two layers. There is early a marked differentiation in the two layers, the outer becoming thinner and the inner rapidly increasing in thickness, especially at the posterior portion of the eye where the cells take on a radial arrangement. The outer layer eventuates into a single row of cells, hexagonal in shape assumed to be so by some to thus better withstand the mutual pressure to which they are subjected. Later they take on pigment and form the pigmented layer of the retina. Therefore, embryologically the retinal pigment layer is really a part of the retina. Where the two layers of the secondary vesicle are continuous, viz., at the anterior margin of the cup, is the point which corresponds to the margin of the pupil in the fully-developed eye. The starting point of the optic nerve fibres are the cells of the ganglionic layer of the retina, thus corresponding to the posterior root ganglia of the spinal nerves. From these ganglionic cells fibres grow along the optic stalk towards the brain and in this manner the optic nerve is formed, thus gradually replacing the optic stalk. Originally, the lens vesicle formed by a down growth of cuticular epiblast completely fills the cavity of the secondary vesicle, no vitreous cavity having as yet been formed. The lens vesicle is pinched off from the cuticular epiblast due to the intrusion of mesoblastic tissue. At first the ocular cup is deficient below due to the fact that an infolding takes place forming a cleft. This cleft or fissure is known as the fœtal cleft or choroidal fissure and it is through this that the vessels which are derived from the surrounding mesoderm enter the eye. The vitreous cavity is formed by the intrusion of the mesoderm carrying its vessels through the ocular cleft, between the posterior walls of the ocular cup and the lens and by the development of the vitreous body. Thus the vascular elements within the eye retain their connection with the remainder of the mesoblast. The choroidal fissure is continued backwards for some distance upon the pedicle of the optic nerve in the form of a furrow and thereby allows a process of mesoblast to extend down to the stalk to form the central artery of the retina with its vein. The origin of the vitreous is still a matter of controversy. It has been long held that it was developed from the mesoblast. Other high authorities, among them Fuchs, hold that the vitreous is of epiblastic origin and that it takes its origin from the cells of the inner layer of the ocular vesicle, in other words from that which ultimately becomes the retina and mainly from its anterior or ciliary portion. As the vitreous develops it crowds the lens away from the bottom of the ocular cup against its anterior wall. The lens is first a thickening of epiblast, then an involution forming an open follicle, then a cavity closed by epiblastic

cells. The cells which form the inner wall of the cavity, which is to become the lens, increase rapidly in size, become elongated and form fibres which fill up the cavity and convert it into a solid body. The cells on the anterior wall undergo no change and retain their cellular character. The lens lies in direct contact with the ectodermal lining. At the point of involution of the epiblast, the external layer separates from the ball of the lens and passes freely over its surface. The lens disconnected from the epiblastic layer recedes into the hollow of the ocular cup, while the cuticular layer covering it is developed into the epithelium of the cornea. While the lens is completely filling the ocular cup, there is no anterior chamber. The mesoderm grows in from all sides at the anterior margin of the ocular cup between the lens and the cuticular epiblast. There is a splitting of this mesodermal tissue, the anterior leaflet of which forms the substantia propria of the cornea, and the posterior leaflet forms the iris and pupillary membrane. The mesodermal tissue surrounding the secondary optic vesicle is at first a non-differentiated mass of cells which later forms through its outer layers the sclera and cornea, and through its inner layer the uvea. The ciliary body and iris are formed from a spur of the latter layer which insinuates itself between the lens and the cornea, carrying on its posterior surface the anterior wall of the optic vesicle. This latter later becomes the pigmented layer of the iris. The growth of the bent-over, thin edges of the optic cup continues until only a small opening, the pupil, is left. The stroma of the iris is of mesodermal origin and is without pigment at birth. Therefore, all new-born infants' eyes appear blue. Later pigment is deposited in the stroma. Pigment is not deposited in the choroid until about the seventh month. As the iris stroma is developed from the mesoderm and grows unequally in all directions from the anterior part of the ocular cup, the choroidal fissure is in no way concerned in its development, and cannot therefore alone be held to explain the occurrence of colobomata of the iris and ciliary body. The vitreous space, even while yet small, is traversed by a set of vessels, the network of vessels over the posterior surface of the lens. These vascular elements of mesoblastic origin have intruded themselves through the choroidal fissure. That set of vessels passing through the vitreous to the posterior lens surface is a continuance of the central artery of the optic nerve and is called the hyaloid artery. It lies in a canal known as Cloquet's canal. The hyaloid artery breaks up into a vascular network on the posterior surface of the lens giving rise to the tunica vasculosa lentis which provides for the embryonic growth of the lens, but which later undergoes complete atrophy. This vascular tunic

after spreading out on the posterior lens surface, approaches the equator and bends over it on to the anterior surface and forms a system of loops. The tunica vasculosa lentis has reached its highest development at the seventh month, after which it degenerates. That part which is on the anterior surface of the lens may fail to undergo complete retrograde changes and persist after birth as a thin membrane closing the pupil. This represents a different fibro-vascular structure than the one on the posterior surface of the lens. It grows in in front of the lens behind the cornea and it is between this fibro-vascular membrane and the cornea that the anterior chamber is really formed. Its vessels, however, communicate with the posterior tunica vasculosa lentis which contains no veins, and some other means of carrying off the venous blood is provided. The retinal vessels grow out from branches of the central artery of the optic nerve and push their way into the nerve fibre layer of the retina. The lachrymal gland develops during the third month as a solid upgrowth of ectoderm from the conjunctival sac into the mesoderm underlying the upper lid. These upgrowths are at first solid but later become hollowed out, forming a lumen. Diverticula are sent out from the main stem which are likewise solid and later acquire a lumen. The lachrymal ducts are early developed in a groove between the maxillary processes, externally, and the outer nasal processes internally. The lids begin early as protrusions of the integument a short distance from the corneal margin. They continue to grow, their margins meet and unite in front of the globe. The enclosed cavity forms the conjunctival sac. Shortly before birth the epithelial union of the lids is dissolved.

Ablepharia. Ablepharia is a term used to designate the congenital absence of the lids. The condition is sometimes met with in anophthalmia. It may be partial or complete. The partial forms are probably better described as microblepharon in which cases the incomplete lids may take the form of nodules or narrow folds of skin, surrounding an ill-developed or rudimentary eyeball. It is frequent where microblepharon is present to find concomitant defects in the eyeball, clefts in the lid of the opposite side or anomalies in other parts of the body. The condition of ablepharia is very rare. As to the genesis of the defect, we are in doubt. It may be that it represents a failure of development. It is possible the processes of ectoderm which spring from above and below and go to form the lids failed to bud. Again the lids may have formed in the normal way and been destroyed by undue pressure of the amnion or amniotic bands. Cases are described and the subject treated by Fuchs, Seiler and Gallenga.

Coloboma of the lids. Coloboma of the lids is rather a rare anomaly.

Parsons states that up to 1906 about a hundred cases had been reported. Not many have been added since then. It occurs both unilaterally and bilaterally, and one or both lids of an eye may be involved. Usually; however, it is the upper lid. The commonest occurrence is the involvement of but one lid. There are very rare instances where all four lids were affected. The shape of the defect is generally a circumscribed triangular one with the base at the lid border and the apex directed towards the orbital margin. In other cases the shape is more rectangular. At the lid margin the corners are often rounded off, whilst occasionally the defect is clean cut, as if it were punched out, with straight sides and pointed corners. The defect may range in extent from a mere depression or nick in the lid margin in the least marked cases, to one involving a large part of the lid. As a rule the whole thickness of the lid is involved. As the lids are not formed by the approximation of two laterally developing plates, there is no chance for a failure of development in this manner to occur, as is observed in other regions of the face, consequently there is no typical site for these defects. Most of the cases, however, are formed more nasal-ward than temporal-ward. In rare cases more than one coloboma has existed in a single lid. An incomplete form may occur characterized by an absence of tarsal tissue, whilst the conjunctiva and skin are present. Where the defect does not reach to the orbital margin it occasionally is continued to that point as a cicatricial band. The edges are covered with soft reddish conjunctiva which may also partially fill the angle and connect the lid with the conjunctiva of the eyeball.

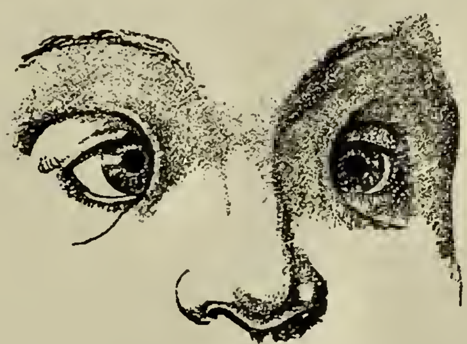
Meibomian and sebaceous glands and cilia are usually absent in the region of the coloboma. The lashes abruptly stop at the angles and show a decided tendency to converge at that point. The defect is quite frequently filled with a bridge of skin which extends onto the globe, and even to the cornea. In the latter case marked corneal opacities are generally present. This bridge of skin is true skin and contains as constituent parts, papillæ, sebaceous glands, fat and hairs. Its presence may seriously interfere with the movements of the eyeball. The under surface of this band at its borders may possess an appearance of mucous membrane whilst the upper may in part appear red and moist similar to mucous membrane, and in other parts possess the usual appearance of dry skin. In quite a number of cases in the absence of a bridge of skin, there is found between the borders of the coloboma a dermoid springing from the sclero-corneal margin. A lipodermoid may likewise occupy this situation. This occasionally is multiple. Where such is the case, diffuse corneal opacities are likewise present.

In those rare cases in which the outer commissure is absent, there occurs a formation of tissue resembling a pterygium. It is exceptional that a coloboma of the lid exists as the solitary defect. It is generally associated with other defects of the eye or anomalies in other parts of the body. Opacities of the cornea have been mentioned in connection with the presence of dermoids and lipodermoids.

Coloboma of the iris is a common finding. Less frequently are found conical cornea, microphthalmia, corectopia, persistent pupillary membrane, and anterior synechia of pupillary membrane, as seen in one case (Van Duyse). In the instances in which the nick in the lid border is shallow and the lashes continue across the defect this can hardly be classed as a true lid coloboma, but rather as a distortion of the lid.

In the large majority of the cases the puncta and canaliculi are normal and the lachrymal passages are patent. At times a dacrocystitis is present. In exceptional cases in coloboma of the lower lid, two puncta are found, one on each side of the defect. Other defects of the lids frequently occur and the orbital border may be notched. Occasionally in cases of upper lid coloboma the defect shows a continuation upwards in the form of a defect or absence of the eyebrow, either complete or incomplete. Symblepharon, blepharoptosis and dermoid of the lid rarely occur. A wedge-shaped patch of hair may extend from the hairy scalp towards the orbital border in those cases where a coloboma of the eyebrow is present. On the lids in the region of the coloboma occur at times cutaneous growths. In the same cases there may also be present tags of skin on the side of the face and accessory auricles. The imperfect closure of the facial cleft between the frontal and maxillary processes is held to explain some of the cases of lid colobomata, viz., those lying in the line of the cleft. Here the lid defect is interpreted as being the continuation of the fissure. If the colobomata were always so situated and occupied an oblique position, and especially if in those cases of combined upper and lower lid defect, the upper defect occupied a temporal position relative to the lower one, then we would be forced to conclude that lid colobomata were developmental defects. In some cases the situation of the former fissure is represented by a fibrous scar, the coloboma being a continuation of the same. The simultaneous occurrence of bodily defects which are known to be the result of undue pressure of the amnion or amniotic bands, brings this etiologic factor in the foreground. As instances of these defects may be mentioned exencephaly, spontaneous, amputation of extremities, syndactylism, cleft-palate, hare-lip, and macrostoma. The earlier accepted explanation of lid colobomata

was that they were developmental defects. The researches and observations of Van Duyse have quite satisfactorily established the fact that in a measure they are developmental, in that the pressure or attachment of abnormal amniotic bands may prevent the proper growth of the lid. Should the lid happen to be normally formed the presence of similar bands could bring about a destruction of a segment of the lid producing a coloboma by a subsequent contraction. The later absorption of the bands could occur leaving behind no trace other than the damage done. The cutaneous-like structures found on the lids and eye-ball, viz., dermoids, lipodermoids, bands or bridges of skin, and the pterygium-like formations, can be interpreted as the remains of these amniotic strands. The contention of those opposed to this theory,



Double-sided Epicanthus. (After von Hippel.)

for the reason that amniotic bands cannot account for symmetrical defects, is answered by the observation of bands passing symmetrically over the lids and finding attachment to the cornea (Bruns, Pollailon and Lannelongue). The colobomata of the eye-brow and the occurrence of tongue-shaped hairy patches of the forehead are sufficiently met by Van Duyse's theory.

Epicanthus. Epicanthus is the abnormal development of a fold of skin at the inner angle of the eye due to the excessive development of the skin over the root of the nose. The fold passes from above downwards from one orbital margin to the other. Its edge is concave with the concavity directed outwards. The concave edge is free. The fold is of varying width in individual cases and not always equal in the two eyes. It hides the caruncle and even a goodly portion of the lids. The fold may be obliterated by pinching up the skin over the bridge of the nose. The condition may give to the child an appearance of apparent strabismus. At times an actual strabismus is present. The lachrymal puncta are often hidden by the fold. A probe may be passed beneath it showing that there is no connection between it and the

lid margins or caruncle. The folds represent simply duplicatures of skin which are in direct connection with the skin of the bridge of the nose. Epicanthus is a rather common anomaly. It is usually bilateral, von Ammon alone describing a unilateral occurrence. In mild cases with the development of the bridge of the nose the condition tends to correct itself. Typical epicanthus is always found at the inner angle. Because of the similarity of a condition which was observed at the outer angle, Sichel and Chevillon described it as epicanthus externus. The absence of similar observations makes it improbable that a true external epicanthus occurs as a separate entity. The presence of a fold at the internal canthus gives the child a somewhat sleepy appearance, due probably to the fact that the palpebral aperture is narrower than usual. There is often noticed a subnormal movement of the eyelid due to a partial ptosis or weakness of the levator. A condition somewhat analogous to epicanthus is normal to the Mongolian race in which the bridge of the nose remains flat. Those children with epicanthus have therefore been referred to as Mongolian types and have been thought to represent examples of atavism. The admixture of Mongolian blood has also been suspected. Both of these suppositions can in most cases be positively ruled out. The spontaneous cure due to the growth of the nasal bridge certainly speaks against such views. The influence of heredity is quite marked. One of the commonest of facial characteristics handed down from a normal parent to his offspring is the configuration of the nose. Therefore it is not especially remarkable that epicanthus should occur commonly in many members of a family. It is only the less marked grades of epicanthus which undergo spontaneous cure, the more marked cases remain as a deformity throughout life. The more marked cases are frequently associated with other congenital defects, prominent among which is ptosis. The connection of these two defects often manifests a marked hereditary tendency. Huettemann published his observations on congenital ptosis with epicanthus in three generations of one family. Two brothers affected were illegitimate sons of a father likewise affected. One brother had four living children of whom three were affected. The other brother also had four children, three of whom were affected. Except in one case no disturbance of the other ocular muscles was present. Examination of the electrical reactions in three cases suggested the absence or imperfect development of the levator. The unaffected children resembled the mothers. Steinheim reported a similar series of cases showing the relationship of epicanthus, ptosis and heredity. Sichel-Vignes saw ptosis and epicanthus in thirteen persons belonging to four generations.

Ankyloblepharon. Ankyloblepharon is a union of the edges of the eyelids throughout part or all of their extent. In the former case it is designated as blepharophymosis and in the latter as true ankyloblepharon. It is commonly found accompanying anophthalmia and microphthalmia. Where the union is simply due to a failure in the normal separation of the lids in the latter part of intrauterine life, such union is purely epithelial. Where the lids are firmly adherent it is usually the result of a preëxisting ulcerative condition. Some cases are attributed to injury in pre-natal life. This is given as a cause, especially in those cases characterized by the union of the lids by a filament. The fingernail is considered a causative factor. (Wintersteiner). In blepharophymosis there is a diminution in the breadth of the palpebral fissure as a rule at the expense of the outer angle.

Ankyloblepharon Filiform. (After Webster.)

It is worthy of note that in the latter condition enophthalmus and nanophthalmus are frequently present. There is a tendency to confuse ankyloblepharon and cryptophthalmia. A case reported by Coover is described as cryptophthalmia, but in some respects answers to the description of ankyloblepharon. In cryptophthalmia there is no differentiation of the lids except possibly a thin, horizontal line or depression marking the site where the lid margins should have been. No Meibomian glands or cilia are present, whereas in ankyloblepharon the constituent parts of the lids are intact. Where a string or thread varying in size and length is present connecting the lid margins the condition has been given the name of *ankyloblepharon filiforme adnatum.* This condition is usually unilateral. A few cases are on record where it was bilateral. These bands are usually extensile, but may limit the movements of the lids to a greater or lesser extent. Such bands are made up of connective tissue and blood vessels with a covering of epithelium and have been proven to be of undoubted inflammatory origin. Reis examined a thread microscopically and showed it to consist of a core of elastic tissue and capillaries surrounded by several layers of epithelial cells. The formation of the thread is explained as follows: The threads are formed by two capillary loops lying

opposite each other. These loops are pushed forward as a result of some injury in late fœtal life and join each other at a time when the lids are joined together only by epithelial cells. When the normal separation takes place this strand of tissue formed by the capillaries fails to give way, and is drawn out into a thread by the movement of the lids. Wintersteiner found the thread attached between the cilia in front and the Meibomian ducts behind. Opposite the insertions of the filament the ciliary bundle of the orbicularis palpebrarum was poorly developed. The filament is frequently situated at the junction of the middle and outer third of the lid margin.

Cryptophthalmia. Cryptophthalmia is a rare condition. Zehender recorded the first case. This patient was examined by Manz in 1872. Since then cases have been recorded by Hocquart Chiari, Van Duyse (two cases), Fuchs, Otto, Bach, Karmann, Coover, Guensberg and Eberhardt. Guensberg suggested that probably the cause lay in an hereditary predisposition. Coover's cases tend to support this. He describes a mother and two children affected. In cryptophthalmia we have a condition of total congenital ankyloblepharon and symblepharon. Where a fold of skin passes directly from the forehead to the cheek without differentiation into lids, it seems improper to use the previous designation, total ankyloblepharon, yet it is so described by all writers. There is, without exception, in cryptophthalmia a marked abnormality of the globe and frequently of the orbit. The condition is as a rule bilateral. Abnormalities in other parts of the body are common. Syndactylism, malformation of the genitalia, hare-lip, cleft-palate, meningeal encephalocele, atresia of the larynx, ventral hernia and aplasia of the kidneys have all been observed. A number of attempts have been made to do something for this condition in an operative way but the result has always been the same, complete failure. The lids re-adhere to the globes. The conjunctiva is tightly adherent to the eyeball and when dissected free the globe is found of a purplish or dusky color. Usually no pupil is found and no fundus reflex is obtained. At times some light perception is present, as is proved by movement and wrinkling of the skin when a strong light is directed towards the eye. This wrinkling is also indicative of the presence of the orbicularis though it is probably always much attenuated. Guensberg examined a cryptophthalmic eye enucleated by him and from it and other published cases concluded that the origin was an inhibition in development and in no way due to an embryonal inflammation, as any cause which may inhibit the development of the lens, such as the late separation of the lenticular sac, might delay the development of the anterior segment of the globe. Skin passes

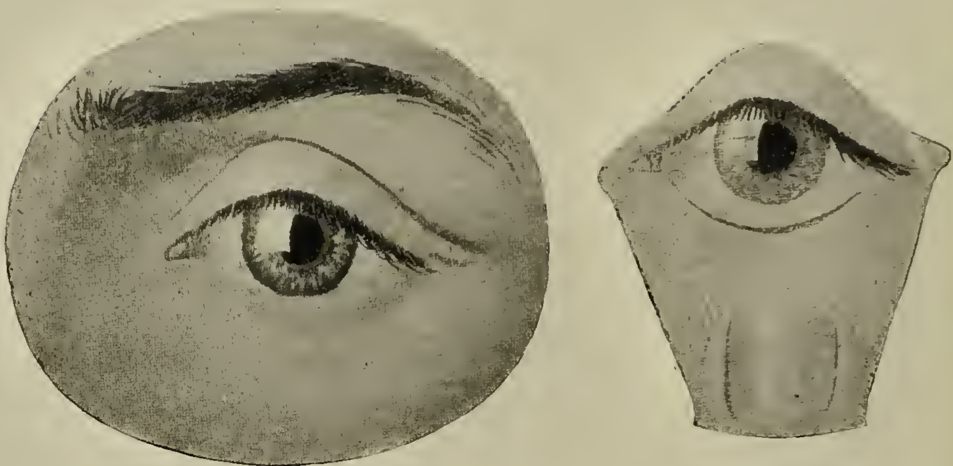
continuously from the upper to the lower orbital margins. The palpebral fissure is usually indicated by a faint line or depression. The eyelashes are absent, the eyebrows generally present. The eyeballs may be seen and palpated as spherical prominences. Movements limited in extent occur, showing the presence of extrinsic muscles. In Coover's one case two rows of hairs were present midway between the lower margins of the upper lids and the margins of the orbit. Probing along the site of the palpebral fissure fails to reveal any opening. Usually no corneal tissue can be demonstrated microscopically, the small globe being imbedded in a mass of connective tissue. In the skin covering the globe, Meibomian glands and the tarsus are usually absent; Bach, however, found them present. The globe is always in a very much disorganized condition. The cornea matted together with the conjunctiva is not distinguishable as cornea. The iris is distorted, adherent and atrophied. The lens may be displaced, shrunken, or even absent. As to the cause we are still in the dark. Whether the lids are not formed and the conjunctiva then develops into skin, as suggested by Collins, or the lids and conjunctiva are fused, or the lids are destroyed and replaced by amniotic bands, which later take on the qualities of skin, we are unable to state with any degree of certainty. The hypothesis of pressure by the amnion as an etiologic factor, while difficult to apply to bilateral cryptophthalmia, is no more so than it is in bilateral coloboma of the upper lid, of which undoubted instances exist.

Symblepharon. A complete symblepharon is the constant finding in cryptophthalmia. In some few cases of other defects associated with conjunctival tumors, a symblepharon has been found but cannot be accepted as congenital, for the reason that the conjunctival irritation set up by the tumor probably produced the symblepharon. Chance reports a case of symblepharon associated with corneal opacities and a fibro-fatty tumor, all of prenatal origin, but admits that he must regard the opacities and symblepharon as of inflammatory origin. Partial symblepharon is at times found with coloboma of the lid. With these exceptions symblepharon is not met with as a congenital anomaly.

Entropion and Ectropion. Congenital entropion and ectropion occurring as isolated anomalies are exceedingly rare. Guibert concluded that a defective development of the tarsus was the cause of the incurving of the lid. Occasionally entropion is found in connection with epicanthus. Entropion most frequently occurs, however, with anophthalmus and microphthalmus. In microphthalmia with cysts, although the lower lid be distended and everted (ectropion), the upper

lid falls into the hollow above and turns inward constituting an apparent entropion. An increase in the size of the globe, whether from buphthalmia, orbital cyst or anterior staphyloma is conducive to the formation of ectropion. In all of these cases there may be a defect in the musculature of the lids.

Epitarsus. Under this designation have been described cases by Harlan, deSchweinitz and Schapringer. Schapringer drew attention to the peculiar formation of an apron-like fold of conjunctiva on the under surface of the upper lid. The folds may nearly equal in breadth the breadth of the lids, but diminish towards the free edge of the lid. A probe may be passed beneath them.



Distichiasis with Absence of Cilia. (After Traquair.)

Trichiasis. The investigations of Stephenson show this not to be such a rare anomaly. The paucity of reports on it are probably due to lack of observation and to not thinking it of sufficient interest to report. Some of the cases are no doubt instances of entropion, especially those attributed to imperfect development of the tarsal plate. Cases are described in which the intermarginal strip was said to be normally situated.

Distichiasis. This is another rare anomaly. In a few of the reported cases the element of heredity was observed (Casey A. Wood, Westhoff and Erdmann). There is found a second row of more or less well-developed cilia occupying the site of the ducts of the Meibomian glands. Other cases are reported by Becker, Hernheiser, Kuhnt, Zirm and Ischreyt. The condition has been studied microscopically by Kuhnt who found the Meibomian glands missing and their place taken by the second row of cilia. Traquair reported a case of congenital deficiency of cilia and intermarginal area of both lower lids with distichiasis.

Accessory eyebrows. Accessory eyebrows have been described occurring as isolated patches in the temporal region of the same color and quality as the normal eyebrow. Such a case is reported by Dodd.

Muscle anomalies. Muscular anomalies are relatively not very rare. The literature of late years contains many references to various anomalous conditions. Ptosis, however, is by far the commonest. Its association with epicanthus has been noticed by many observers. Heredity here plays quite a conspicuous part. It is most frequently bilateral, though unilateral cases appear especially in conjunction with other

Congenital Ptosis with Associated Lid Movements of the Affected Eye. (After Thomson and Souter.)

muscular anomalies. It occurs possibly equally in both sexes. The isolated cases are frequently attributed to injury at birth. When looking straight ahead the defect may not be very noticeable. In other ones the patient assumes a characteristic appearance. The skin of the forehead is thrown into transverse folds by the action of the occipito-frontalis. It is by this means that the patient lifts the eye-lid sufficiently to uncover the lower portion of the pupil. The loss of power in the levator may be complete or incomplete. In the former, the drooping is greater and in addition to the use of the frontalis the patient tilts the head backwards. Frequently there are defects in the development of the other muscles about the eyes. Paterson reports a peculiar phenomenon observed by him affecting a four-year-old girl, with right ptosis. There was a cyclical contraction and dila-

tion of the pupil, the whole cycle consuming thirty to forty seconds. The size of the pupil when dilated being 5 mm. and when contracted 2½ mm.; extreme dilatation or contraction not being reached at any stage of the cycle. The movements are wave-like or oscillatory. The ptosis varied during the pupillary cycle but this was not very marked. Other cases are reported by Axenfeld and Schürenberg, and Franke. Levinsohn observed a six-year-old girl with paralysis of the right oculomotor and continual changes in the size of the pupil. Light and convergence exerted no influence, but adduction caused dilatation.

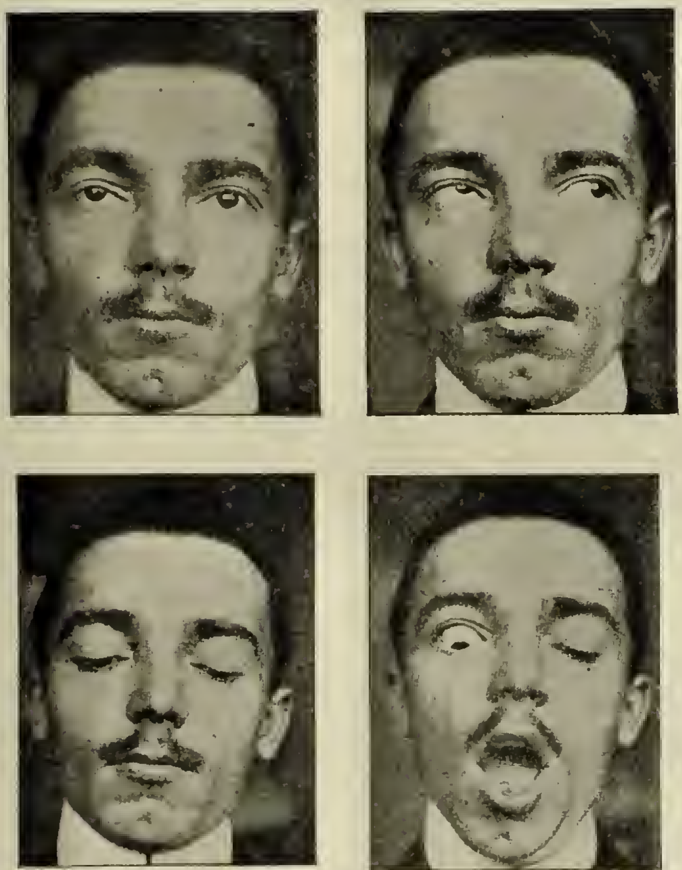
Congenital Ptosis with Associated Lid Movements of the Affected Eye. (After Thomson and Souter.)

Contraction of the orbicularis caused pupillary contraction. A spasm of 2.5 to 3 D. was demonstrated by skiascopy, accompanying contraction. Levinsohn located the lesion in the nucleus and roots of the oculomotor nerve.

These cases represent a well-known type characterized by more or less complete third nerve palsy and rhythmic changes in the pupil. With ptosis there is at times a defective development of the facial muscles with epicanthus to which the term, "mask-like epicanthus," has been applied. Another interesting condition is that of ptosis with associated movements wherein movements of the jaw produced striking effects in the lid suffering with ptosis. Marcus Gunn early drew attention to these phenomena. Thompson and Sauter have

given a detailed description of a case observed by them in a girl of nine years with ptosis of the left upper lid. Upon working her jaw to the right a marked upward jerk occurred in the left upper lid exposing 2 to 3 mm. of sclera. Coburn's patient showed complete ptosis except that the upper lid could be raised by opening the mouth.

In the non-hereditary cases of ptosis there is usually defective movement of the globe upwards. Other external muscles supplied by the third nerve are frequently involved. The pupillary action and accom-



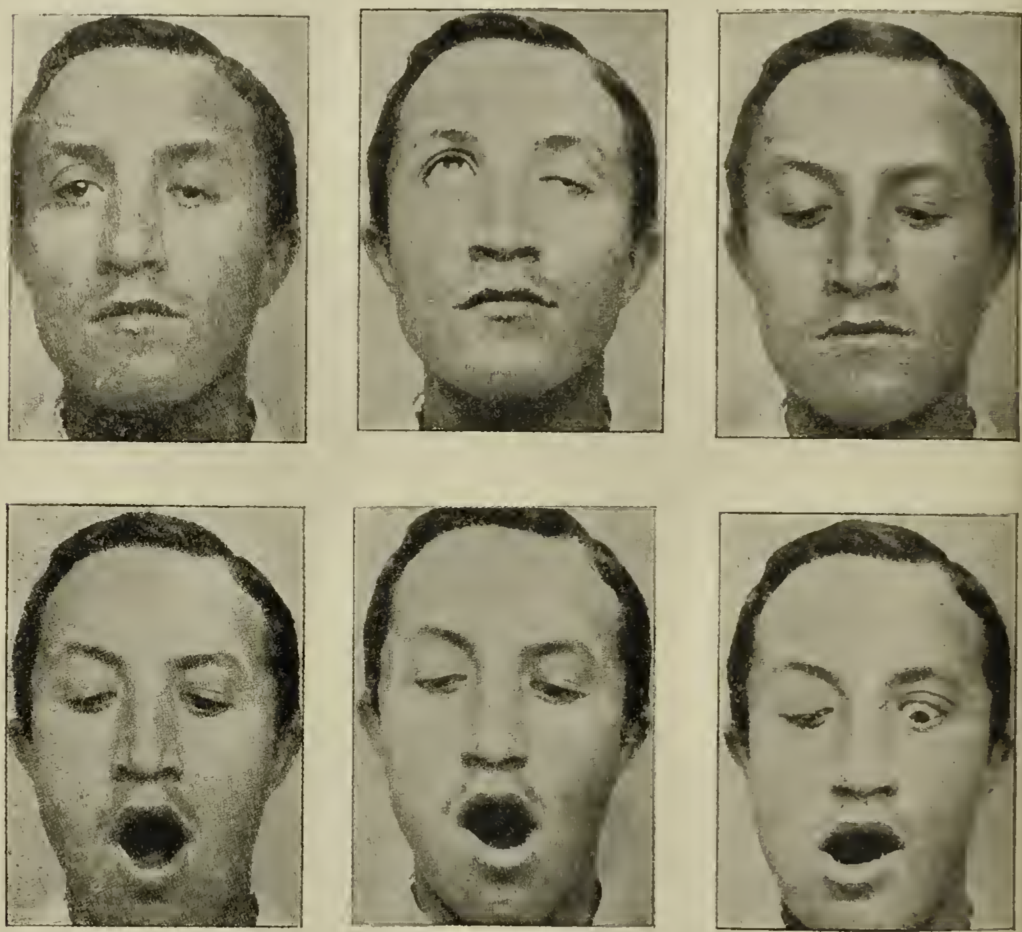
Ptosis with Associated Movements. (After Lutz.)

1, Looking straight ahead, no abnormalities seen; 2, Looking to the left and downward, paresis obliq. sup. A.; 3, Looking downward, no abnormalities seen; 4, Opening the mouth and raising the lid.

modation are said to be always normal, the cyclic dilatation and contraction above noted being an exception. Stephenson takes issue with this statement and cites cases refuting it. He draws attention to the fact that these patients are brought for advice at an early age when the recognition of paralysis of accommodation is out of the question.

Strabismus and nystagmus are sometimes present and vision is often much reduced. Next to the levator palpebræ the commonest

muscle to be affected is the external rectus, usually on both sides. Other cranial nerves, notably the seventh, may be palsied. Ptosis due to birth injuries or forceps should be carefully differentiated from congenital ptosis. The birth palsies are of very frequent occurrance.



Ptosis with Associated Movements. (After Lutz.)

5, Looking straight ahead. Ptosis. 6, Looking upward. Paresis levat. palpebr. et. rect. sup. sin. 7, Looking downward. 8, Opening the mouth. 9, Moving the jaw to the same side. 10, Moving the jaw to the opposite side.

The cause of these muscular palsies is in dispute. Authorities are divided into two camps, muscular and nervous. Those advocating the muscular theory hold that these defects are due to absence, imperfect development or abnormal insertion of the individual muscle or muscles involved. This contention is supported by numerous anatomical investigations and has been met with, much to the chagrin of an operator, during an attempted muscle operation. Coover observed in a woman absence of the superior and inferior recti when he tried to perform advancement of the seemingly paralyzed muscles. Heuck

demonstrated post-mortem a defective levator on one side and its absence on the other in a young man who, during life had ptosis, and absence of upward and downward movements of the globe. The latter defect was due to an abnormal insertion of the superior and inferior recti. Instances of bifurcated muscles are noted (Dieffenbach-Behr). Muscles are found merged together or with union of neighboring parts. Morgagni found a union of the superior oblique with the trochlea. Olbers and Wrisberg also report fused muscles. Abnormal insertion of a muscle or muscles were noted by Rossi, Dieffenbach, Pflüger and others. Wicherkiewicz found when making an advancement of the internal rectus that the internus was inserted by two tendons separated vertically from each other by a distance of 4 mm. This space decreased backwards so as to form a triangle with its apex in the belly of the muscle 16 mm. from the line of insertion. Faulty insertion as a cause has received the support of Harman. Such insertions are normal in lower vertebrata. In still other cases muscles have been found to be replaced or represented by fibrous bands or strands. Cases are reported by Ahlstrom, Uthoff, Baumgarten and others. Ter Aruntinjanz at an operation for strabismus found the internus tendon very broad and adherent to the sclera by an insertion above the normal one. The superior rectus was very strongly developed while the inferior rectus consisted only of a feeble tendinous bundle. Complete absence of muscles occurs. Steinheim records the superior rectus absent, Lawford the internal rectus, Seiler, the right superior rectus, and both inferior and obliques, and Harles both obliqui. The evidence in favor of the nuclear theory of congenital ophthalmoplegia is based on anatomical studies and inference. Willbrand and Saenger found imperfect development of the third nerve nuclei in a man with congenital bilateral ptosis. Hübner, in a child with sixth and seventh nerve palsy and incomplete paralysis of the left third nerve, found the medulla incompletely developed, and an atrophy extending from the olivary body to the nuclei. The brain showed no changes. Various writers, Lawford, Fryer, Werner, Möbius and Schapringer have inferred the existence of a nervous origin, based upon the fact that an internus, acting badly or not at all with the externus, yet performed convergence well. Babronneix and Harvier report a case of congenital facial and ocular paralysis. Deviation of the mouth and double-sided convergent squint was noticed. They found left facial paralysis of peripheral type and incomplete external bilateral ophthalmoplegia. The muscles involved were the external recti and both obliqui on each side. They assumed a failure of grey matter on the left side, extending from the eminentia teres

to the posterior end of the nucleus of the third nerve, and on the right side localized to the nuclei of the sixth, fourth and neighboring part of the third nerve. Accepting the muscular theory, we would have to imagine the absence or defect of all muscles involved in those cases where many muscles are affected, as in McCubbins', and Babonneix and Harvier's cases. Furthermore, anatomical investigation in some of these cases has revealed a normal condition of the muscles. It would therefore appear that both theories are based upon fact, but that the acceptance of one does not necessarily exclude the other. It is also very likely that a muscle, or muscles, being deprived of their nervous supply would develop very poorly, or, having been developed, would degenerate and ultimately be represented by a fibrous band. The nervous theory does not, however, account for the complete absence of muscles. Stephenson is inclined to attribute most cases of congenital ophthalmoplegia to an affection of the nuclear centers which govern the defective movements.

Congenital ophthalmoplegia externa is described by Cooper. The family reported by him is quite remarkable. There were a series of cases in the same family. The original patient was found to have immovable eyeballs and ptosis. Investigation revealed the fact that the father, grandfather and great grandfather were similarly affected. So far as the father could remember, no female member had been affected; all the cases were congenital and ptosis had been complete in all the affected, except his own youngest son. The following tree was prepared by Cooper:

Great Grandfather *

Male — Gt. uncle * — Grandfather * — Female — Female

Uncle * — Father * — Male, Died in asylum

Died 2 days old — Male — Died in infancy — Son A.* — Female — Son B.*

Two children not affected

*—those affected

McCubbin reported the case of a boy six weeks old in whom there was bilateral ptosis and slight unequal dilatation of the pupils which did not respond to light. The right eye converged, the left was fixed in the primary position. There was no proptosis. The discs were pale. Passive movement was tried with no effect. The pupils responded to eserine and atropine. The case was described as one of congenital immobility, extrinsic and intrinsic. The lesion was considered central with probable fibrous replacement of the muscles.

Retraction syndrome. There occurs a peculiar association of ocular movements characterized by congenital deficiency of abduction with retraction of the globe and contraction of the palpebral fissure. This phenomenon, or series of phenomena, exists as a definite syndrome. Attention has been called to it by various writers, but one of the best dissertations on the subject is furnished by Duane, who collected and reviewed fifty-four cases. Since then some twenty odd more cases have been reported. John Green, Jr., has personally observed four cases and does not think the condition is so very rare. It occurs as follows: 1. Complete or less frequently incomplete absence of outward movement of the affected eye. 2. Complete or incomplete deficiency of inward movement of the affected eye. 3. Retraction of the globe when adduction is attempted. 4. Oblique movements of the eye up and in or down and in when adducted. 5. Partial closure of the eyelids when the eye is adducted. 6. Paresis or deficiency of convergence. The affected eye remains fixed in the primary position while the sound one converges. The first complete account of this condition was given by Wolff. The retraction is not invariably present, being sometimes absent when the other features are marked. In these cases as in all other congenital muscle anomalies, there is no contracture of the opposing muscle. In this syndrome the eye usually cannot be brought past the median line in abduction. If the eye be directed upwards or downwards the obliqui may slightly abduct the globe. Adduction may be normal, restricted or absent. Even if adduction is well performed it cannot be long sustained. Oblique movements occur when the eye is adducted or moved up or down, being up and in when directed upwards, and down and in when directed downwards. Torsion movements on attempted abduction occur, due probably to spasmodic action of the obliqui. Retraction, while a striking feature, is not always present and may be present in but a slight degree. When present it varies from 1 to 10 mm., though the amount of retraction may be more apparent than real. It occurs upon adduction or attempts at adduction. In the same case the amount of retraction may be variable. An enophthalmos often exists with the eye at rest in the pri-

mary position. On attempted abduction the eye often protrudes, usually but slightly in amount. In a large majority of the cases adduction or even attempted adduction is accompanied by a closure of the palpebral fissure. When abduction occurs the palpebral fissure frequently dilates somewhat. The contraction of the fissure is a result not of ptosis but of contraction of the orbicularis. Convergence is usually subnormal. If the eyes be directed away from the side of the deficient internus convergence may then be fairly well performed. The head is often carried to the side to avoid diplopia or tension. There is more or less restriction of passive movement. In a few cases orthophoria is present in the primary position. The majority, however, show divergence or convergence. There is generally a pronounced secondary deviation of the sound eye. Nystagmus and nystagmoid movements at times are noted. The affection is more frequent in women and on the left side. The subjects of this anomaly may complain of ametropia, asthenopia, diplopia and vertigo. The absence of abduction is probably due to the absence of the externus. Deficiency of adduction is due either to abnormal insertion of the internus or the pressure of an inextensible cord replacing the externus. Retraction may be due to faulty insertion of the internus (Henck), or an accessory slip to the internus acting as a retractor (Bahr), to a deficiency of the check ligaments (Collins), to the inextensibility of the externus (Wolff), or to the action of the superior and inferior recti (Peschel). The closure of the palpebral fissure is doubtless an associated movement. Insufficiency of convergence is probably due to hindrance, due to the action of the internus. Oblique movements are due most probably to excessive spasmodic contraction of the inferior oblique (Duane).

Opacities of the cornea. A discussion of corneal opacities is closely related to that of congenital anterior staphyloma. Whether the causes leading to either of these conditions be developmental ones or the result of an intrauterine inflammation, or ulceration, the process may be looked upon as a mild circumscribed one which results in opacities, or a more violent and destructive one which leads to anterior staphyloma. Congenital opacities may be complete or partial. In the description of keratoglobus mention is made of the fact that the cornea is opalescent and hazy and much enlarged. This is no doubt a result of the stretching which seriously interferes with the nutrition of the cornea. Complete opacity of the cornea occurs at times in connection with microphthalmia. Most of the congenital opacities are permanent though some may exist for but a time and gradually disappear. Partial opacities may be centrally or peripherally situated and exhibit

varying degrees of intensity. Some are dense white, while others are but nebulæ. Opacities are frequently associated with other very pronounced congenital defects besides microphthalmia and anterior staphyloma, such as dermoids, anterior synechiæ and colobomata of the iris and choroid. Some of the band or tongue-like opacities, as for instance those met at times with lid coloboma, may find their explanation in the pressure of the amnion or the remains of amniotic bands. Where a dermoid is present this appears even more likely. A condition similar to arcus senilis is at times met with to which the names arcus or annulus juvenilis, embryotoxon and macula arcuata have been applied. The external ring of clear cornea is here present as in the adult type. Hereditary congenital corneal opacities are described. Komoto reports an instance in a patient forty years old with a congenital diffuse opacity of the cornea, whose two children and a nephew suffered with the same complaint. No vascularization was present. The idea of fœtal keratitis he thought improbable because of the similar picture in four patients. Opacities are at times associated with changes in the shape or curvature of the cornea. In some instances the line of demarcation between sclera and cornea is not clear, the sclera as it were appearing as if continued on to the cornea. This is usually densely white in color and has been termed sclerophthalmus. But few cases of total congenital opacities of both eyes are found recorded in the literature. Armaignac reported two such, one a child of three months old with an almost total gray-blue opacity of the cornea of each eye without signs of inflammatory changes. The only transparent portion was a zone 2 mm. broad in the periphery. The surface of the cornea was smooth and lustrous. Another child born four years before had the same trouble. He states that in the majority of the cases the affection gets well without trouble. The case belongs to that of total gray or blue-white non-inflammatory opacities in contradistinction to those of inflammatory leucomatous changes in the cornea with consecutive degeneration. Chance described a case showing a symblepharon, corneal opacity and a fibro-fatty tumor, all of pre-natal origin, in which one eye showed an oblique, densely opaque white line 1 mm. wide across the cornea. The rest of the cornea was clear and lustrous. In the other eye a broad, dense, pearly-white scleral tongue extended 3 mm. within the limbus. The tongue was continuous with the sclera, the corneal surface not elevated and the remaining portions clear. In some of the cases of corneal opacities, as in Armaignac's case above cited, there is a suspicion of syphilis. Congenital pigment in the cornea is at times observed. Tweedie found a small nebulous spindle-shaped central opacity of the cornea con-

sisting of small, yellowish-brown dots of pigment which were more numerous in the center. It appeared to be situated just back of Bowman's membrane. The other eye was similarly affected to a less degree. Sallfner in a new-born horse found pigment opacities in the cornea. Von Hippel reported the findings of two cases of internal ulcer of the cornea and one of parenchymatous keratitis, the latter in a thirty-three weeks' old fœtus, from which cases he draws conclusions bearing on the formation of corneal opacities. In the thirty-three weeks' old congenitally syphilitie fœtus spirochætæ pallida were found within the eornea. A eorneal opacity was not found but the finding of the spiroehætæ speaks with great likelihood he thinks for the entrance of the parasite into the cornea as preliminary to the inflammatory eondition. Von Hippel thinks that internal ulcer of the cornea has a certain significance in the explanation of congenital staphyloma of the cornea and leucoma. Seefelder reported three cases of eongenital corneal opacity and thinks that the results are of inflammatory origin. In two eases the vascularized corneal sears, and in one case the complete loss of the eornea, shows that the eyes were affected during intrauterine life by a severe inflammatory proeess. He concludes that the larger part of congenital leucomata are due to a prenatal inflammation of the anterior uveal traet with a simultaneous and consecutive involvement of the eornea, and attributes his three cases to that cause. Mohr found eight patients with congenital corneal opaeity out of sixty thousand eye patients. He discussed these cases with regard to three questions; whether they are due to an arrest of development according to Peters, or to intrauterine inflammations, according to Von Hippel, chiefly eharacterized by formation of an ulecr at the posterior surfaee of the eornea, or if they gave any information whether the inflammatory proeess from outside (amniotic fluid) is more probable than a merely intra-bulbar one. Some facts seem to speak for an arrest of development; others decidedly for a primary inflammation. (The diseussion of the probabilities of an endogenous or exogenous infeetion of the cornea will be taken up in considering anterior staphyloma.) The cases of adherent leucomata constitute an intermediate class between corneal opaeities on the one hand and anterior staphyloma on the other. Many authorities, probably the majority, among them Von Hippel, Parsons and Seefelder, strongly support the inflammatory theory of the cause of corneal opacities. Others adhere to the developmental theory, among them Collins and Stephenson. In fœtal life for a time, the length of which is not certain, the eornea is opaque. It is never at any time, according to Seefelder, vascularized. The presence therefore of vas-

cularized scar is taken as confirmatory evidence of the inflammatory origin of corneal opacities. All scars or opacities, however, are not vascularized.

Interstitial keratitis. Opacities resembling interstitial keratitis are met with. They vary in extent and degree of density. The changes are in the deeper parts of the cornea and clear up after birth, generally from the periphery towards the center. A syphilitic history may or may not be present.

Congenital staphyloma. Congenital anterior staphyloma is a rather rare anomaly. Parsons mentions a number of cases described in the literature in most of which a microscopical examination was made. The condition of congenital anterior staphyloma resembles closely that in post-natal life following a perforating ulcer. The cornea is

Bilateral Congenital Anterior Staphyloma of the Eyeball. (After Sydney Stephenson.)

opaque and bulges forward between the lids, reaching at times a large size. It is lined behind by uveal pigment which, shining through the thinner portions, imparts to them a bluish color. The cornea proper is replaced by a tissue resembling cicatricial tissue and the membranes of Bowman and Descemet are totally absent or present only at the periphery. This iris is much stretched, thinned, its stroma is atrophied but the pigment is present, and adherent to the posterior surface of the cornea. The lens may be in its normal position, shrunken and dislocated, or entirely absent. Due to the pull exerted on the ciliary body, it is much distorted. Where the staphyloma is so large as to protrude between the lids, they cannot be closed and the exposed part may become keratinized. The color of the protrusion is not always bluish, being at times whitish, and again a reddish, fleshy color. The condition is met with bilaterally and unilaterally. In the unilateral cases the other eye often shows some other defect such as corneal opacities, phthisis bulbi, and microphthalmia. The conjunctival sacs

are well-formed and may show no evidence of a recent inflammation. In a few instances a family tendency has been noted. The most remarkable is that of Steinheim's in which out of a family of six, four were born with either anterior staphyloma or corneal opacities. Two theories have been evolved for explaining the occurrence of anterior staphyloma, the ulcerative theory and the malformation, or non-differentiation theory. Most writers support the former. The latter is supported by Collins and Stephenson. The ulcerative or inflammatory hypothesis presupposes the existence of an intra-uterine ulceration of the cornea with the sequence of events following similar to those in post-natal life. As to the manner in which a congenital anterior staphyloma occurs, where it is due to a perforating ulcer, it is supposedly the same as that of one in infancy. A considerable area of the whole thickness of the cornea is destroyed by ulceration, the peripheral parts alone remaining intact. The inflamed iris is thus exposed and is prolapsed forwards filling the gap. Granulation tis-

Eyeball in Bilateral Congenital Anterior Staphyloma. (After Sydney Stephenson.)

sue grows from the anterior surface of the iris and later becomes converted into fibrous tissue and a pseudo-cornea is formed. The anterior surface of the pseudo-cornea soon after its formation is covered by epithelium which grows over it from the undestroyed cornea at the periphery. The stroma of the iris, due to stretching, undergoes atrophy, leaving behind its pigment lining, the posterior surface of the pseudo-cornea. The normal relationship of parts being changed, the aqueous finds escape impossible, due to the obliteration of the usual channels. Hence, tension becomes increased, the pliable cornea stretches, and thus becomes staphylomatous. Advocates of the developmental theory point to the frequent complete absence of Descemet's membrane as being inconsistent with the idea of a pre-natal ulceration. Treacher Collins has revived the old theory of non-differentiation of the mesoblast concerned in the development of a substantia propria, hyaline layer of Descemet's membrane, its lining endothelium and the anterior fibro-vascular sheath of the lens, as the cause of congenital anterior staphyloma, and he points to the findings of his case for substantiation. There was found present no Descemet's membrane, no iris stroma, the lens small, flattened and otherwise malformed and an abnormal anterior situation of the ciliary processes. The develop-

mental theory as urged by Collins seems to bring the explanation of anterior staphyloma in close relationship with buphthalmus, for if the mesoblast fails to properly differentiate, especially that portion forming the ligamentum pectinatum, there would be no channels of exit for the aqueous and buphthalmus, and not anterior staphyloma should be expected. Congenital anterior staphyloma is to be regarded as a result therefore of either an ulceration of the cornea, or of an ophthalmia arising from an infected amniotic fluid, which infection must have taken place at a period considerable in advance of birth. Evidence in favor of the ulcerative theory receives confirmation in the fact that whereas in other congenital defects, due to developmental

The Cornea in Bilateral Congenital Anterior Staphyloma. (After Sydney Stephenson.)

causes, there are often associated defects in the parts of the body other than the eye, it is not true of this anomaly.

In the cases of congenital anterior staphyloma recorded by Parsons, no mention is made of other defects apart from those of the eyes. The fellow eye, however, showed changes in some of the cases, as in Crampton's two cases there was a corneal opacity in the other eye, in Krückow's case microphthalmia, in Hirschberg and Birnbacher's phthisis bulbi, in Westhoff's a shrunken and opaque cornea, in Lawson and Coats' microphthalmia, with opacities of the cornea. In Collin's case the fellow eye showed a nebula of the cornea. As an exception to this, Stephenson reported a case of bilateral staphyloma which showed the following anomalies: 1 A slit-like prolongation of the outer canthus resembling in its formation a macrostoma. 2 Micro-

cephalus. 3 The growth of a tuft of hair from the helix. 4 Monorchism. 5 Mongolian type of little finger. 6 Genu recurvatum.

The occurrence of bilateral cases is urged in favor of the ulcerative theory. In two of Steinheim's cases the condition was bilateral. Stephenson's, referred to above, also was bilateral but after a histological examination of his case, Stephenson adhered to the developmental theory. The bilateral occurrence is a strong point in favor of the exogenous infection from the amniotic fluid. In two cases, one described by Swanzy, and the other by Bernheimer, the anterior staphyloma was composed of a mass of dermoid tissue. Collins thinks

Congenital Anterior Staphyloma. (After Treacher Collins.)

Shows the posterior surface of the cornea, with the pigment epithelium of the iris in contact with it. Note complete absence of Descemet's membrane, ligamentum pectinatum, and stroma of iris.

it impossible to explain these two cases on the supposition of a corneal ulceration, but attributes them to a pushing forward of the staphyloma between the lids and as a result of exposure to the same fœtal influences as other superficial parts of the body, the cornea develops a skin-like surface. Objection is raised to this interpretation on the ground that while it will explain the skin-like formation, it will not explain the development of hair and adipose tissue in these dermoids. A point made by Collins in support of the developmental theory, viz., the forward displacement of the ciliary processes, is met by Coats, who explains this phenomenon as being but part of a general displace-

ment forward of the whole ciliary body which in fœtal life is but loosely connected with subjacent structures. In post-natal life this connection is firm so that this anterior displacement is missing in staphyloma occurring after birth.

Points in favor of the developmental theory are: (a) Complete absence of Descemet's membrane. (b) Forward displacement of the ciliary processes. (c) Absence of or badly-developed iris stroma. (d) Absence of all signs of inflammation. (e) Absent, shrunken, or malformed lens. (f) Absence of signs of conjunctival inflammation. (g) Absence of concomitant bodily defects. (h) Unilaterality of most cases. (i) Closure of the eyelids throughout most of fœtal life.

Points in favor of the ulcerative theory are: (a) Findings in some cases of remnants of Descemet's membrane at the periphery. (b) Clinical appearance identical with post-natal staphyloma. (c) Presence of vasularized cornea. (d) Occasional bilateral staphyloma. (e) Corneal opacities in fellow eye. (f) Presence of uveal pigment lining the pseudo-cornea and proving the previous formation of the iris.

It is seen that most of the points in favor of non-differentiation are negative, whereas in the other view they are chiefly positive. The conception of how anterior staphyloma occurs and the acceptance of the ulcerative theory becomes very easy if we could but explain how the infection provocative of the ulceration is brought about. Endogenous infection has been considered a possibility, but its acceptance entails so many steps in the process that it has received but scant recognition. The possibility of metastatic transmission of pus bacteria from the mother to the fœtus has been satisfactorily demonstrated by experiments on animals, usually by injections of pure cultures into the mother. As the cornea is in fœtal life an avascular structure direct infection endogenously would not occur. Infection from the amniotic fluid has received most support and is probably more plausible, but the explanation of how the infection reaches the amniotic fluid possesses many difficulties. The gonococcus has been suspected of being the infective agent but in many cases the mother has been absolutely free throughout pregnancy of any vaginitis. Many other germs than the gonococcus might be held responsible. That the amniotic fluid can become infected in apparently healthy women, is proven by numerous instances of its occurrence. Even a putrid condition due to infection by the colon bacillus has been noted. Infection can possibly reach the amniotic fluid by three routes:

First, through the placenta; secondly, from the uterine mucous membrane; and thirdly, from the vagina. The route through the

placenta is the more circuitous and must entail a lesion of the placenta permitting infection. Infection from the uterine mucous membrane is the more direct route but it must itself be infected either through the circulation, from the vagina or from previously diseased adnexa. The cervical canal early in pregnancy is closed by a plug of mucus which tends to prevent direct invasion of the uterus or fœtal envelopes. The occurrence of infection by any of the routes must be exceedingly uncommon and exceptional, otherwise congenital anterior staphyloma would be a much more frequent condition. Even granting amniotic infection as present, it is necessary to admit a break in the epithelial union of the lids, which ordinarily exists till near the end of pregnancy, in order that an infective agent could attack the

Child, Aged Nine Weeks, with Congenital Anophthalmos. (*Royal Lond. Ophth. Hosp. Reports*, Vol. XI.)

cornea. Considering the situation from all sides, it would appear that the strongest arguments made by thorough observers and authors are in favor of the ulcerative cause of congenital anterior staphyloma, the chief difficulty being in explaining how the infection reaches the cornea.

Anophthalmia. Anophthalmia denotes the apparent absence of an eye or eyes. A division can be made into true anophthalmia in which not a vestige of the eye is found, and apparent or clinical anophthalmia where more or less rudiments are found on anatomical or microscopical investigation. True anophthalmia is exceedingly rare though there are undoubted cases on record. (Klein.) The great majority of cases belong to the second division. In more than seventy per cent. of recorded cases the condition is bilateral. As these children are often, though not always, badly malformed in other respects, they die

early leaving no offspring so that a direct heredity is not possible. Some slight collateral heredity has been shown but not in a striking enough manner to arouse comment.

As an explanation of true anophthalmia, it is perfectly conceivable that a failure of the primary vesicle to bud from the thalamencephalon might occur and hence give rise to the complete absence of the most important elements of the eye. Mesoblastic tissues might still be present though in a poorly-developed or rudimentary state. That such actually occurs is shown by the results of anatomical investigations. As it is usually met clinically and diagnosticated there is an apparent absence of the eye to such an extent that it is not macroscopically demonstrable or capable of being palpated. The orbital cavity is small and conical and at its apex is a soft reddish mass representing the rudimentary eyeball. The ocular muscles may be more or less developed and are inserted into the subconjunctival tissue of the mass at the apex of the orbit. The differentiation of the muscles is, however, very poor. As the presence of the eyeball is probably necessary for the proper development of the orbit and lids, we find the orbit usually much diminished. The lids are narrowed, short and a condition of microblepharon or partial ankyloblepharon is present. The cilia are scanty and badly formed. The edges of the lids may be turned in constituting an entropion and giving rise to conjunctival irritation. Where the condition is unilateral, the other eye may be found normal. Von Hippel records the condition of the existing fellow eye in twenty-three cases as follows: Fifteen were normal, four were microphthalmic, one showed coloboma of iris and choroid, one hypermetropia and nystagmus and one grayness of the optic nerve. The optic nerve may be present and be in places fairly well developed but it is usually reduced to a fibrous cord. The proximal portion of the nerve may show a fairly normal appearance from near the optic foramen to the soft, reddish mass at the bottom of the orbit, the rest of the nerve being reduced to a band of connective tissue. It is usual to find the optic foramen much reduced in size or totally absent. In the unilateral cases movement of the eye elicits movements in the mass in the apex of the orbit on the anophthalmic side, proving the presence of muscles. The lids, while seldom absent, may be so reduced in size as to be but mere tags of the skin. When better developed, their muscular constituents may be demonstrated. When the extra-bulbar muscles are present, the nerves likewise are. As exceptions to this may be mentioned the reported cases of Bartscher and Gradenigo. The lachrymal gland is said to be always present, whereas the puncta and canaliculi may be absent or closed in one or both lids.

Serious bodily defects are frequent accompaniments of anophthalmia, such as anomalies of the head and brain, asymmetry of the face, defects and malformations of the ear, hare-lip, spina bifida, malformations of the heart and other internal organs. The constituent defects in closest relation to the eye are those of the brain and tracts. The chiasm, corpora quadrigemina and external geniculate bodies may be either badly developed or missing. Schiperskaja endeavored to indirectly solve the question of whether anophthalmia was due to a concomitant brain defect or to an inflammatory origin by making intellectual tests of five anophthalmic girls from five to thirteen years of age. Four were deficient, and one an idiot. These observations, while of interest, do not clarify the situation. Regarding the etiology of the condition, it may be explained in one or two ways. Either the optic vesicle failed to bud, in which case no development could proceed, or, having budded and developed, it was destroyed more or less by some intra-uterine inflammatory or purulent process. Von Hippel quotes a number of cases including one of his own where a purulent conjunctivitis was present at birth. Boulai reported a case of double total anophthalmia in a seemingly otherwise normal child. The conjunctival sac was very narrow, had a red, granular appearance and was covered with a turbid serum. Hoppe does not think that stress should be laid in the presence of conjunctival irritation or even the presence of a discharge. He attributes these to the concomitant entropion and the entrance of amniotic fluid into the conjunctival sac, with the subsequent infection from the vaginal discharges during the passage of the fœtus. He cites an observation of the presence of blennorrhœa in nine out of ten cases of anophthalmia.

Greeff found in a little girl a right anophthalmia with two deep furrows running obliquely upward and downward from the outer canthus. Slight macrostoma present on right side. There was a rudimentary hare-lip and cleft-palate, with a large bone defect at the upper edge of the right zygoma. Colobomata of the left upper and lower lids were present. Greeff explained all these malformations as due to amniotic bands and adhesions during intra-uterine life.

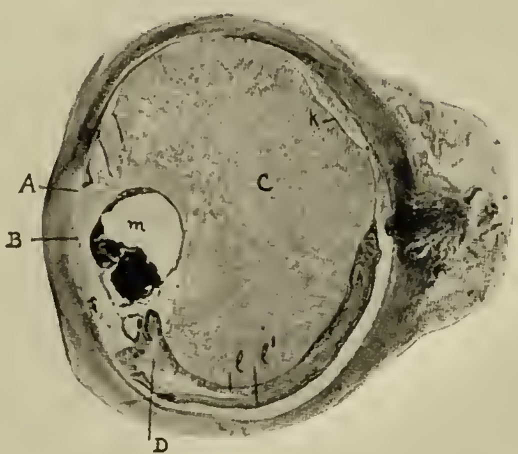
Just how much importance is to be given to such findings it is difficult to state. There are arguments pro and contra yet it would seem that in a large number of the cases of clinical anophthalmia, the explanation doubtless resides in the ante-natal destruction of the eye caused by an inflammatory or purulent process.

If we admit the possibility of an exogenous infection in explaining the production of congenital anterior staphyloma then the process carried to a further degree could produce anophthalmia. On the

other hand, the frequency of defects in the development of parts of the brain, especially of those structures vital to the integrity of visual conduction, the absence at times of the olfactory lobes, failure of all evidence of epiblastic elements, very small size and even absence of the orbit, point to developmental faults as the most likely explanation in this particular class of cases. Pressure of the amnion might be looked upon as a cause of destruction of the eye.

Many cases of so-called anophthalmia are in reality high-grade examples of microphthalmia. Especially is this true in the cases of orbito-palpebral cysts in which cases a rudimentary eyeball is always found to be present.

Microphthalmia. In the early literature on this subject Beer, in 1813, was one of the first to draw attention to this striking anomaly.



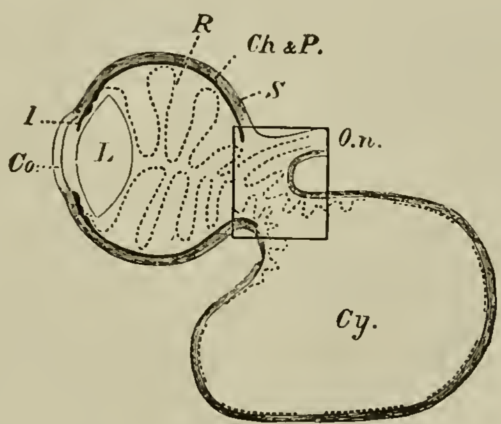
Microphthalmia. (After Coats.)

General view of the globe. A, Anterior chamber. B, Anterior division of the posterior chamber. C, Posterior division of the posterior chamber, almost completely filling the globe. D, Vitreous, much shrunken. The mesoblastic strand is not cut at this level. k. Sheet of inner layer of the optic vesicle which has undergone distension. It lines the choroid on the nasal side and crushes the nasal retina over to the temporal side. l, Nasal retina. l′, Temporal retina. m, Lens. (*Ophthalmoscope*, Oct., 1910.)

Since then it has been well described and studied macroscopically and microscopically by numerous observers. It was early noticed that it seldom existed as the only anomaly present and that colobomata, principally of the iris, were frequently combined with it. Microcornea was recognized as being the simplest form of microphthalmia. From that to the cases where the eye elements are but rudimentary, all gradations are found. When careful anatomical observations, both of the eye and the rest of the body, particularly the brain, were made it was found that hemicephaly, microcephaly, idiocy, encephalocele and other defects of brain and body occurred at times, concomitantly. This naturally brought up the question as to whether one was dependent on the other or not, or whether all were the result of a common cause.

Van Duyse has divided microphthalmia into three classes: 1. Nanophthalmia, where the eye is normal but small, this diminution in size constituting the only defect. 2. Microphthalmia, with coloboma of the iris. 3. Microphthalmia with extensive malformations and great reduction in size. To the latter class belong naturally those cases with cyst formation. It seems strange that all writers have seen fit to describe along with microphthalmia with orbito-palpebral cyst, cases designated as anophthalmia with cyst. The latter can be nothing else than a high grade microphthalmia with cyst production. The transition from clinical anophthalmia to microphthalmia is one rather of degree than kind. As has been mentioned, anophthalmia is often a high grade microphthalmia. At the other end of the scale are those cases which deviate from the normal only in size and have been designated as nanophthalmia, or dwarf eye, which may be a proportionate reduction, in keeping with the general bodily reduction of dwarfs. It is, of necessity, a rare condition. It is often found to be bilateral, but numerous cases of unilateral microphthalmia have been reported in the literature. In later life the size of the eye may remain stationary or diminish somewhat. Arlt reported a case in which the eye actually grew considerably in after life. Cunningham likewise reported a case where growth of the eye was said to have occurred but the observation was made by the mother. The same defects of brain and head may be present as are found in anophthalmia, viz., asymmetry of the face, contracted orbits, microcephaly, etc. The vision is, as a rule, amblyopic, in many cases very much so. Light perception is generally present even in bad cases. Pyle reported a case where in view of the reduction in the size of the eye, he considered the vision to be extremely good. Nystagmus and strabismus are frequently found present. The orbit is often reduced much in size. At other times it is equal to its fellow (Rust, Cunningham). The lids may be normal or show a reduction in size in keeping with the eye and the orbit. When the lids are of normal size, it is especially noticed that they may turn inwards and the conjunctiva be thereby much irritated by the cilia. In other cases the lids are much narrowed and shortened, resulting in a small palpebral fissure. The upper lid often assumes a drooping appearance, due to some deficiency in the structure or innervation of the levator palpebræ. Extrinsic muscles, except in the very high grade cases, approach the normal so that movements of the eyeball are generally fairly well accomplished. On movement of the good eye, the microphthalmic one often follows surprisingly well. Attempts at ocular movements often brings out a nystagmus and accentuate a strabismus.

Due to the flattening of the sclera at the points of insertion of the tendons of the recti muscles, the diminutive eye may take on a more or less quadrangular shape. The ocular conjunctiva sometimes is of sufficient quantity and area to cover the sclera of a normal sized eye in a full sized orbit so that it nearly buries the diminished eye and allows but little of the cornea to be visible. The cornea is often quite small and flattened. The orbicularis muscle is usually present but the tarsal plate may be absent. Owing to the flattening of the cornea, the anterior chamber is shallow. There is at times slight differentiation of cornea and sclera so that the line of demarcation is not clear. The cornea does not always show opacities or defects being frequently



Diagrammatic Representation of a Microphthalmic Eye with a Cyst Attached. (*Royal Lond. Ophth. Hosp. Rep.*, Vol. XII.)

Co, cornea; *L*, lens; *I*, iris; *R*, retina much folded; *Ch* and *P*, choroid and pigment epithelium; *S*, sclerotic; *O.n*, optic nerve; *cy*, cyst lines by atrophied retina.

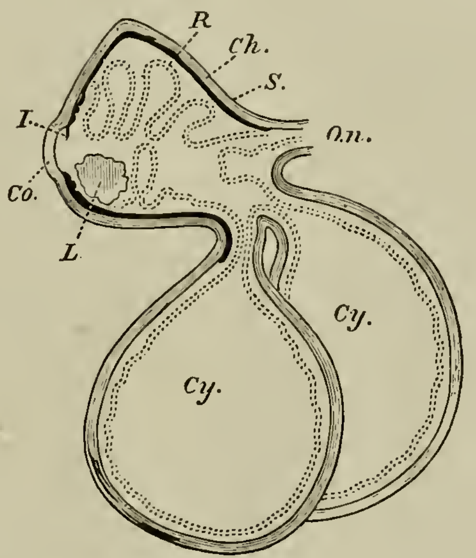
perfectly clear and transparent. In the other cases the cornea is vascularized and shows bands, streaks or tongues of opacity. Hanke reported the cornea replaced by a dermoid. Because of the striking frequency of coloboma of the iris as a feature of microphthalmia, Van Duyse gave it a separate classification. In the slightest grades of microphthalmia the iris may be virtually normal, and react well. In the other cases no reaction occurs, the amblyopia being extreme, or because occlusion or seclusion of the pupil is present. Aniridia, pupillary membrane and corectopia are not infrequent concomitant conditions. The lens may be comparatively large (Bock and Cosmettatos). Frequently it is shrunken and displaced and may show opacities and coloboma. The lens has been reported as completely absent, in other cases the lens may be shriveled to such an extent that little besides its capsule is left. Several explanations have been offered for the complete absence of the lens. One, that it was normally formed and later destroyed, and the other that the primary

optic vesicle was never invaginated by the thickened ectoderm which is the precursor of the lens. The finding of the lens in a position below the non-invaginated primary vesicle would tend to support this view. However, this is very problematical and rather exceptional and the first supposition is probably the true explanation of most of the cases. The ciliary muscle may be absent and the ciliary processes be much shrunken. The vitreous sometimes is reduced in volume or totally absent. Coursing through the vitreous at times are bands of connective tissue carrying with them a vascular development. Hyaloid remains are very frequent. Hyalin cartilage and fat at times found in these shrunken eyes probably constitute an example of metaplasia. Coloboma of the choroid, while frequently found in simple microphthalmia is likewise often ectatic and will be considered under microphthalmia with cyst formation. The retina in marked cases is frequently thrown into folds which nearly fill the vitreous cavity. The retina also is found detached. Cosmettatos called attention to a case where the folded retina filled the whole vitreous cavity. The imperfect development of mesoblast may, as in Mayou's case, form a mass behind a clear lens giving a yellowish-white reflex and carrying vessels on its surface resembling in appearance a glioma. In Mayou's patient the eye was enucleated because of this suspicious appearance. Wintersteiner's retinal rosettes have been observed in microphthalmia. Lafon described this interesting condition in a case of double microphthalmia. He concludes they are not characteristic for glioma and that they develop by invagination of the neuro-epithelial layer into the layers beneath and that the process may take place as a result of developmental arrest. May and Holden found rosettes in the invagination of a secondary optic vesicle lining a cyst. Holden shows that these figures depend on a typical development of embryonic cells which would otherwise form rods and cones. Coloboma of the optic nerve occurs at times with microphthalmia.

Microphthalmic eyes have usually suffered severely either from developmental or intra-uterine causes so that some of the cases coming to microscopical examination proved a veritable pathological laboratory. Corneal opacities, aniridia, coloboma of iris, persistent pupillary membrane, coloboma of ciliary body, retina and nerve, persistent hyaloid artery and a shrunken dislocated lens may be present either singly or some of these together in the same case.

Parsons has reported a most interesting and extraordinary case of microphthalmia with colobomata in conjunction with an orbital meningo-encephalcele. A large mass of brain substance was present in the orbit, displacing the microphthalmic eye outwards. The other

abnormalities were a large staphylomatous bulging on the nasal side, a large coloboma of the optic nerve and coloboma of the macula in which only the pigment epithelium of the retina was missing. The association of double microphthalmia with upward coloboma of the iris in each eye, congenital cataracts, nystagmus and normal tension was noted by Coover. Rochon Duvigneaud and Coutela reported two cases of microphthalmia associated with hydrocephalus. Nystagmus was present in one of the cases. Kitamura examined pigs' eyes with a clinical appearance of anophthalmia with cysts but which proved in reality to be cases of microphthalmia. There was non-differentiation of cornea and sclera, absence of Bowman's and Descemet's mem-



Diagrammatic Representation of Microphthalmic Eye with Two Cysts attached. (*Trans. Ophth. Soc. U. K.*, Vol. XIII.)

Co, cornea; *L*, lens displaced and shrunken; *I*, iris; *S*, sclerotic; *Ch*, choroid; *R*, retina much folded; *O.n.* optic nerve; *Cy*, cysts lined by retina.

branes, aniridia, adhesions of the lens capsule to the cornea. The cataractous lens was lying in the anterior chamber. The choroid was fully developed, the retina rudimentary and the vitreous filled with connective tissue. Coats microscopically examined a globe showing an anterior synechia of a pupillary membrane and iris, a membrane on the surface of the iris, persistence of the fibro-vascular sheath of the lens, backward displacement of ciliary processes, mesoblastic strand in vitreous, coloboma of ciliary body and iris, and ectopia lentis. Von Hippel reported with microphthalmia a complete aplasia of the optic nerve in which a tumor sprang from the retina. The tumor was not a glioma but a benign tumor, springing from the glia. It was considered identical with Helfreich's case which, up to the time of Von Hippel's report, was the only one of its kind on record.

The cause of microphthalmia is still in dispute. There are those who believe that the condition is essentially one of maldevelopment. Others incline to the belief that it is the result of intra-uterine inflammation. Much may be said for each hypothesis. The number of strong and competent adherents of each theory must demand serious consideration of their claims. It is not unlikely that for given cases each is right, that microphthalmia is not always the result of the same process and that it may be brought about in divers ways. The influence of heredity and therefore a defect in the germ has by some been held to be at the root of the trouble. Observations tending to this view were made by Himly, Falchi, Martin, Reber, Rava, Page and others. Similar observations were made in animals. Loeb collected records of twenty-three families in which thirty-seven of the fifty-two children were affected showing a direct transmission in seventy per cent. Indirect heredity was found in two families with three children all affected. Collateral heredity was shown in nineteen families with fifty-six children and forty-three affected, a percentage of seventy-seven. The direct and collateral heredity figures are very striking. The association of brain defects with microphthalmia arouses the thought that both may be the result of a common cause. Hydrocephalus has been mentioned. Landmann found in a chick embryo, eight days old, the right side of the head fully developed while the left was rudimentary. He attributes the attending microphthalmia to the lack of development of the brain. Pagenstecher in a series of experiments directed mainly to the lens, but which gave other interesting data, found that as a result of feeding naphthalin to pregnant rabbits he was able to produce striking effects in the development of the fœtus. The lens opacities were the most prominent but other defects were also noticed, chiefly those of a hindrance of development. He deduced that his results threw light on the genesis of malformation and tended to refute the theory that all ocular malformations are due to an anomaly of the germ and heredity. Frequently there are found marked defects in connection with the fœtal cleft, with a lack of all evidence of past inflammation, which findings are used as evidence in support of the developmental theory. The presence of mesoblastic tissue in the cleft and filling the vitreous cavity, together with the frequency of persistent hyaloid artery, led Hess to support the developmental theory in simple microphthalmia. This fits in very nicely with Von Hippel's contention that normal expansion of the globe is dependent on the normal imbibition of fluid by the vitreous. It thus follows that the presence of large masses of persistent mesoblastic tissue in the vitreous cavity would prevent this. It is to be remembered that the vitreous

body is not developed from the mesoblast, as was long held, but from the retina. It would appear therefore that the mesoblast entering through the fœtal cleft can have but one function and that it is the carrying of a vascular supply to those developing parts in need of it. When it has fulfilled this mission it should disappear; its persistence, due to hyper-development, or what not, effectually interferes with the future normal growth of the eye. That this persistent tissue is not always present after birth and that the cleft is closed does not militate against the acceptance of this theory. Very often the mesoblastic remains are present in association with persistent hyaloid and dislocation and retraction of the lens. Those who support the inflammatory theory see nothing in the latter statement to weaken their theory but use it as supporting their contention. Unless an eye is examined soon after birth, the finding of admittedly inflammatory evidences is open to the suspicion that they might have occurred after birth as it is well known that these eyes are extremely liable to inflammation. The shrunken globe, flat cornea, vascularized cornea, corneal opacities, choroido-retinitis, and dislocated and retracted lens buried in dense fibrous tissue, are findings supporting the inflammatory theory. The absence of anterior chamber, pupil, cornea and retina in Arlow's case indicated to him that the microphthalmia was due to an early inhibition of development. Bach, thinking that a disproportionately large lens prevented closure of the fœtal cleft, gave it as the cause of microphthalmia. There is nothing really tangible to support this theory.

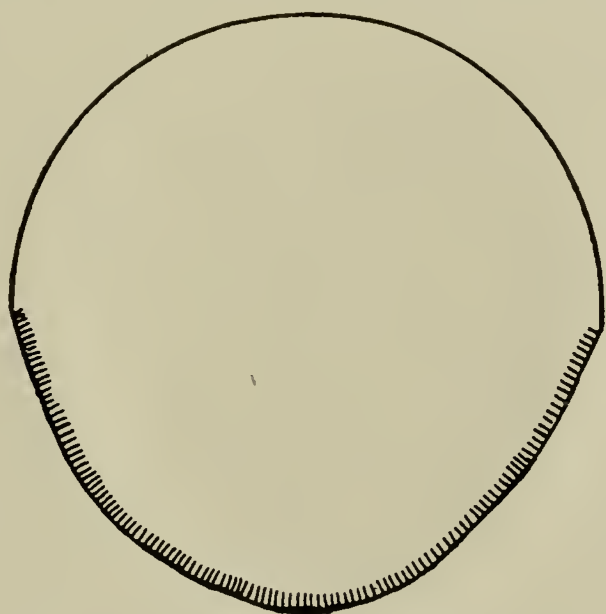
Wessely obtained the following results from operations performed on the eyes of newly born rabbits. 1. After an iridectomy the growth of the eye was very much retarded. This was thought to be due to a diminution in the tension produced by the iridectomy. 2. If the zonule is injured a half-moon-shaped coloboma of the lens is developed during the growth of the eye. 3. If a traumatic cataract is produced the lens regains its transparency in a few months. 4. The regenerated lens always remains smaller than the normal one; the eyeball itself also remains smaller and a microphthalmia results. The size of the eye seems to depend largely on the size of the lens.

Microphthalmic cyst. Microphthalmia along with cyst is usually described as ectatic coloboma of the choroid. Natanson takes exception to this description and likewise to the terms "colobomcyste," "colobome enkysté" and "kyste colobomateux," introduced by Ewetsky and Van Duyse to describe these conditions. The eye in connection with orbito-palpebral cysts is always diminished, varying from but slight diminution to conditions clinically diagnosed as anoph-

thalmia. The cysts usually occur in the lower lids. Cysts of the upper lid rarely occur. May and Holden report such a case. One eye may be microphthalmic while the other is microphthalmic with cyst, or one eye may be normal. Anophthalmia with cyst is really a high grade microphthalmia. The cysts may vary from a size so small as to be hardly distinguishable to a size filling the whole orbit and bulging the lids in front of it. In a case reported by Wicherkiewicz the cyst on the right side reached into the antrum of Highmore. Rarely is the eye of much size, being in the vast majority of the cases not recognizable as an eye. The cyst can be punctured and fluid drawn off. Such fluid was found by Van Duyse to be clear alkaline and albuminous. Wicherkiewicz described it as an albuminous fluid containing red cells and a pigment which is probably derived from the retinal pigment. The cyst may present the parts of a rudimentary eye even including retinal elements (Löhlein). An epibulbar cyst can exist communicating with the interior of the globe, its inner lining continuous with the atypical retina, the invagination of the secondary vesicle being proven by the presence of the pigment layer of the retina. (Kitamura). The condition of cyst is generally bilateral. Natanson states that these cysts occur twice as frequently monolaterally as bilaterally. Sex seems to have no influence on frequency, the cases being equally divided. The palpebral aperture is narrow and the lower lid distended with a firm, smooth, rounded and fluctuating tumor. Because of this, the movements of the lids are interfered with. The lid is thinned and bluish and may be partially everted constituting an ectropion, whereas the upper lid falls inward with a resulting irritation of the conjunctiva by the cilia.

In probably half of the mono-lateral cases there are anomalies of development in the other eye. Anatomical examination reveals the fact that sometimes two cysts are in connection with the microphthalmia. The outer wall of the cyst consists of connective tissue which may be of the type of the sclera. The inner wall consists at times of nerve tissue, which likewise lines the microphthalmus, or of retina, more or less perfect in places, but usually, due probably to the pressure to which it is subjected, some of the layers are missing. The ganglion cell and nerve fibre layer are for the most part wanting. The retina may occupy its normal relationship, or it exists in an inverted condition. This is the so-called "perverse" arrangement. The cyst communicates with the interior of the eye usually through a small opening. The vitreous is found either in the eye-ball, partly in the cyst or completely in the cyst. The choroid is absent in the wall of the cyst, usually stopping at the edges of the cleft, but sometimes extend-

ing a short distance into the cyst. The pigment epithelium disappears entirely or can not be recognized as such. The retina, because of its disproportionate growth in comparison to the globe, is thrown into many folds, which may completely fill the vitreous cavity. It is continuous with that lining of the cyst. Natanson divides the cases into two groups: In group one the cysts are always associated with microphthalmia, which is generally clinically demonstrable and the eye is fairly well formed. On its lower wall directly in front of the optic nerve entrance is a cleft through which the retina protrudes into the cyst, forming its inner layer. These folds completely fill the cleft.

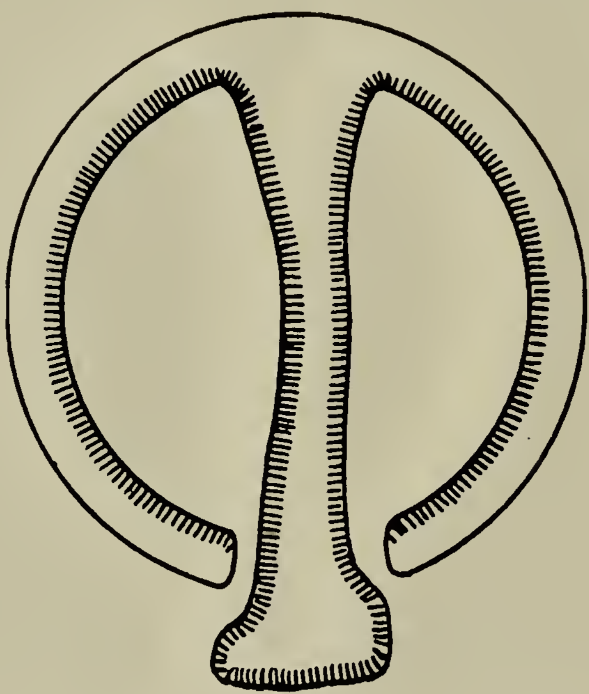


Kundrat's Explanation of Inverted Retina. (After Coats.)

In this diagram the plain line represents the portion of the vesicle which should normally develop into pigment epithelium; the toothed line shows the portion which should develop into retina, and the teeth show the direction of the rods and cones. The normal arrangement is shown on the right hand side of the third following figure. (*Ophthalmoscope,* Nov., 1909.)

There is no communication between the vitreous cavity and the interior of the cyst but the cavity of the cyst communicates with the original cavity of the primary optic vesicle, that is, between the retinal layer proper and its pigment layer. This communication is with difficulty demonstrated. Group two: In this the clinical diagnosis is anophthalmia with the inferior palpebral cyst. In these cases the eyeball has been very poorly developed. Generally but one cyst is found and this has developed on a posterior segment of the eye. Frequently there is a badly differentiated small eye present in connection with the posterior segment of the cyst. The interior of the eyeball is devoid of retina, vitreous and lens. The cavity of the eyeball and the cavity of

the cyst are in direct communication as a result of which the pigment membrane of the eyeball immediately becomes the inner lining for the cyst. The occurrence of cases in Group 1 takes place during the stage of the secondary vesicle, their genesis being due to a delay in the closure of the fœtal ocular cleft. The delay in closure of the cleft in turn being due to the persistence of mesodermal tissue. The retina due to its rapid growth, forms a duplicature on the edge of the optic vesicle which penetrates the neighboring mesodermal tissue. As a result of increased growth of the retina and the formation of fluid between the layers of the duplicature a cyst is formed. In this manner an explanation is furnished for the occurrence of inverted retina,

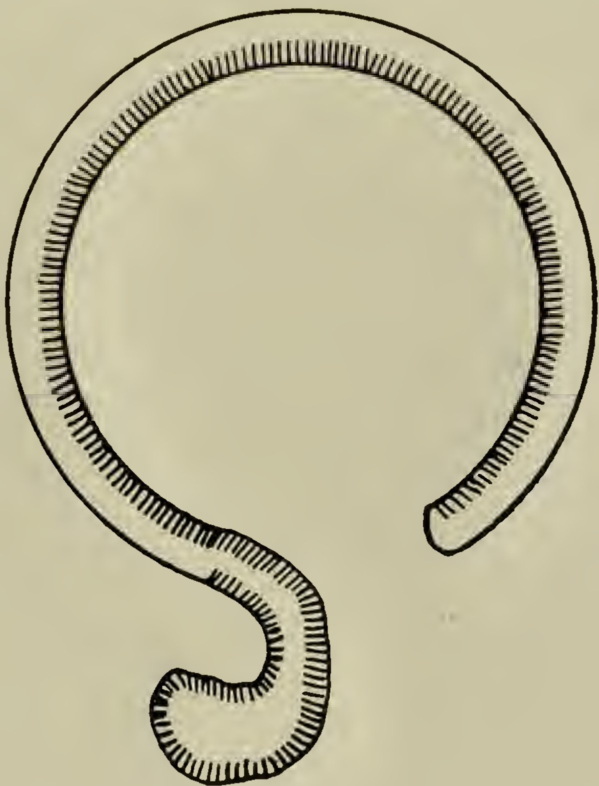


Gallemaerts Explanation of Inverted Retina. (After Coats.)

In this diagram the plain line represents the portion of the vesicle which should normally develop into pigment epithelium; the toothed line shows the portion which should develop into retina, and the teeth show the direction of the rods and cones. The normal arrangement is shown on the right hand side of the second following figure. (*Ophthalmoscope,* Nov., 1909.)

which constitutes the lining of such cysts. In the second group the cysts have their origin in the stage of the primary vesicle. The explanation of the development of the two cysts is that a duplicature of the retina takes place at both margins of the primary vesicle. Of the older and most generally accepted theories are those of Arlt and Kundrat. Arlt sought to explain these cysts as due to an extreme degree of ectasia in the region of a defectively closed fœtal cleft. Kundrat's explanation, which received the support of Czermak and

Mitvalsky, is that the cyst is formed from the non-invaginated primary optic vesicle. Hydrocephalus is occasionally present in these cases. Rindfleisch therefore sought to explain the condition of the eye as a result of pressure from the brain. As against this Von Hippel calls attention to the fact that the eye lies in front of the orbit until the third month and is well protected from pressure from behind. The application of Kundrat's theory to the explanation of perverse retina has been shown to be fallacious. Kundrat and his supporters invoked an incomplete invagination of the primary optic vesicle to form the

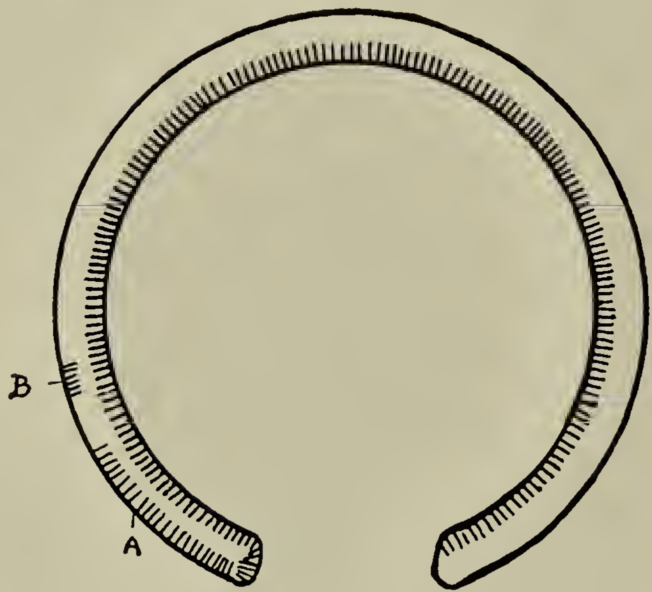


Pichler's Explanation of Inverted Retina. (After Coats.)

In this diagram the plain line represents the portion of the vesicle which should normally develop into pigment epithelium; the toothed line shows the portion which should develop into retina, and the teeth show the direction of the rods and cones. The normal arrangement is shown on the right hand side of the next following figure. (*Ophthalmoscope,* Nov., 1909.)

secondary. In the event of total non-invagination, part of that tissue which eventually becomes retina would remain anteriorly, no vitreous would be formed and the lens would be outside of the globe and the globe would be grossly malformed. In case of partial invagination the anterior parts of the eye might be well formed, whereas the posterior non-invaginated parts would develop into the retina in an inverted condition. If now this perverse or inverted part became ectatic the presence of such perverse retina in the cyst would be explained.

Opposed to this are the findings of cysts in fairly well developed eyes where the opening into the cyst is below the nerve and the anterior and posterior parts of the eye are well formed. To apply Kundrat's theory to such cases would require the invagination of the vesicle in front and behind with a small intervening portion not invaginated, a manifestly impossible condition. Further that part of the retina lining the cyst would have lined the upper part of the globe had invagination proceeded normally and its absence would show itself in a defect of the retina above the nerve, which defects are not found in these cases. Considerable of this explanation of perverse retina is taken from the writings of Coats, who, in a most interesting article on *Misplaced Derivatives of the Secondary Optic Vesicle,* has given us an explana-



Inverted Retina. (After Coats.)

To illustrate metaplastic development of the outer layer of the secondary optic vesicle into retina (at A). The isolated patch of retina at B, corresponds to the patch B in the next figure. Displacement or folding cannot account for such an area. The diagram shows why the outer layer of retina must be inverted. (*Ophthalmoscope,* Nov., 1909.)

tion of perverse retina well worth consideration. According to Coats the strongest argument against Kundrat's theory is that it does not explain the occurrence of inversion with doubling. In the absence of invagination of the vesicle there cannot be two layers of structure derived from it. Gallemaerts has given a theory which, because of its complexity and inapplicability to many cases, has not met with much favor. He supposed that the invagination and formation of the cleft occurred normally and a fold of the inner layer of the secondary vesicle was forced through the still open cleft due to pressure coming from

the cerebral vesicle through the stalk to the optic vesicle. While hydrocephalus is occasionally found with microphthalmia, its presence can have no bearing as an etiologic factor. Pichler expounded a theory which has much to commend it. According to it, the inner and outer layers of the vesicle remain continuous with each other at the edge of the open cleft instead of each fusing with its corresponding layer of the opposite side. The pigment layer is less active in growth in comparison with the true retina and thus the retina outstripping it will at their point of conjunction be displaced outwards and in this manner a fold of inverted retina is formed. If the cleft is open this fold is prolapsed through it into the orbit and forms the lining of a cyst. The smaller the eye, the greater the folding. This likewise does not explain inversion with doubling, otherwise it answers very well as

Inversion and Doubling of the Retina in a Case of Cyclopia. (After Coats.)

A, Pigment epithelium lining of choroid. B, An isolated patch of inverted retina. C, Unpigmented epithelium. D, Inverted retina which is continuous from this point to the papilla. E, Retina with normal arrangement of layers. From the point A onwards the choroid is defective.

an explanation for inverted retina in orbital cysts. Coats makes use of the theory of Haab who accounted for doubling before inversion had been observed. Haab had recourse to the hypothesis of metaplastic development of the outer layer of the secondary optic vesicle into retina. If such be admitted, then that retina is certainly inverted as the inner and outer layers of the vesicle are continuous at the pupillary margin and at the edge of the fœtal cleft. According to the theories of both Pichler and Coats, it will be seen that the cyst cavity will be in communication not with the vitreous but with the subretinal space. Cysts lined with non-inverted retina will generally be found to communicate with the vitreous cavity as this cyst formation represents

simply an invagination of a retina whose integral parts possess their normal relationship. The outer layer of the optic vesicle is, of course, forced out at the same time but, due to its relative thinness and the great stretching to which it is subjected, it is atrophied beyond recognition.

The origin of upper lid cysts cannot be satisfactorily explained. Too few cases have been thoroughly investigated. Ginsberg endeavored to explain their occurrence as the result of a pinching off of a knuckle of the secondary vesicle by mesoblast. This becomes incarcerated though still retaining its connection with the eye. As Parsons states, this theory would explain cysts in any direction but it is remarkable

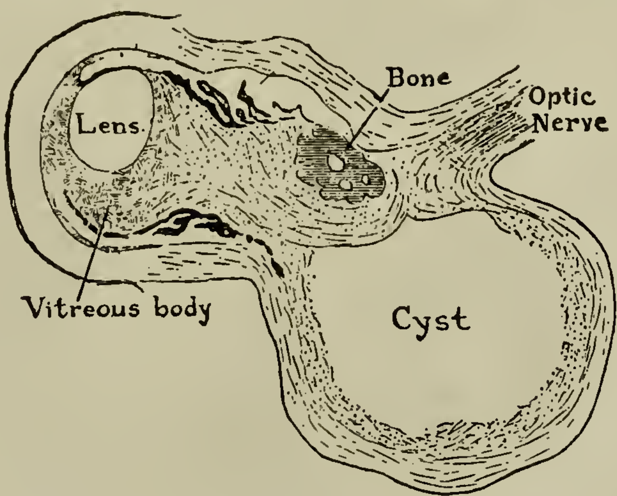
Microphthalmia with Cyst. (Mayou, *T. O. S. U. K.*, XXIV.)

Specimen 2. Above, optic nerve; below, cystic coloboma, with folds of retina passing into it.

that these atypical cysts are so rare whereas atypical colobomata are much more frequent.

The most recent work on the subject of microphthalmia with cyst is by Bergmeister. From the examination of his cases he contends that the neck of the cyst, i. e., the scleral hole, is identical with the optic canal and that the orbital cyst has its origin in an enormous cavity formation in the stem of the eye vesicle. In this way the communications between the cysts and the space between the pigment layer and the parscoptica retinæ are easily explained since in embryonic life this space communicates with the cavity in the optic stem. This malformation takes place most probably in the third month of fœtal life at which time the sheaths of the optic nerve are already formed. The possi-

bility of a disturbing influence on the part of the mesoderm acting on the eye vesicle at a very early period cannot be excluded. The chief disturbance is due to the atypically developed mesoderm in the fœtal cleft. The new observations of Bergmeister in his two cases were that the orbital cysts took their origin in the cavity of the stem of the eye cup. The reasons given for this opinion were: 1. That the walls of the cyst were identical with the sheaths of the optic nerve, there was a dural sheath, and arachnoid with the formation of intervaginal spaces and finally a pia. 2. The presence of a hypoplastic optic nerve trunk which, in the area of the cysts, appeared as an orbital part of the nerve. The lining of the cyst, the zone of the glia tissue showed remnants of an embryonic epithelial covering. 3. The communication of



Microphthalmia with Cyst. (Treacher Collins, *T. O. S. U. K.*, XVII.)

the pathological distended cavities of the stem of the eye cup with a space between the pigment epithelium and the pars optica.

Megalocornea, megalophthalmus, keratoglobus, hydrophthalmus and buphthalmus. These terms, used to describe an enlargement of the cornea or the globe having a congenital origin, were formerly employed interchangeably and as synonyms. Even now some confusion exists in their application. An arbitrary division can be made between those cases possessing a true enlargement of the cornea or globe without other accompanying departures from the normal, and those where the enlargement is a secondary process dependent for its existence upon some diseased condition or anatomical defect. In the first division may be placed megalocornea, megalophthalmus and keratoglobus. In the latter, hydrophthalmus and buphthalmus. Some observers think that the less prominent grade of this class of cases, viz., megalocornea, represents simply the first step in the development

of the condition known as hydrophthalmus. In other words, that these designations are applicable for different stages of what they take to be an identical process. An artificial division has been made between megalophthalmus where no corneal and lens opacities are present, where no cupping occurs and where vision is good, and hydrophthalmia in which just the reverse conditions occur.

The spontaneous recovery of hydrophthalmus though rare, does occasionally occur. Axenfeld has called attention to the fact that keratoglobus and megalocornea may be looked upon as spontaneously cured cases of hydrophthalmus. One evidence of this is the existence of rupture of Descemet's membrane characteristic of hydrophthalmus

Buphthalmia. (From a photograph by Lister.)

in these cases. Parsons states that heredity is well-marked in association with buphthalmus and cites a number of cases to bear out this contention. It does appear to be a family disease as several brothers and sisters may be affected. Loeb, in his investigation of hereditary blindness, did not find that heredity seemed to play a large part, especially direct and indirect heredity. The figures for collateral heredity were more striking. In seven families, with a total of twenty-seven children, twenty were affected, a percentage of 74. As he states, this high percentage is based on the observation of too few cases. The same may be said of the rôle of consanguinity. The attachment and pull of amniotic bands has been used by Van Duyse and others as explanatory of the genesis of this trouble, the accompanying corneal opacities being

charged to the same cause. Those seeking an extra-ocular cause have found the presence of corneal opacities to be inseparably bound up in the explanation of hydrophthalmus. Likewise the theory of faulty development of the cornea. It has been supposed that failure of the cornea to properly clear, resulted in a defective resistance of the cornea, especially at the sclero-corneal junction, so that it gradually gave way before the intra-ocular tension. The presence of opacities and the occasional presence of embryotoxon was taken as confirmatory of this view. It is seen that an increase of tension is not used in explanation but that a pull is exerted from the outside, or that an inherent weakness exists in the cornea. All cases are not accompanied by opacities of the cornea or by embryotoxon so that the theory of faulty cor-

Buphthalmia. (From a photograph by Lister.)

neal development, or amniotic pull, would, even if true, fail to explain a large number of cases. Furthermore the presence of opacities may be looked upon as secondary to the corneal distension. Intraocular inflammatory theories have been invoked to explain these cases. That inflammation might interfere in some way with proper filtration cannot be denied. The occurrence of the so-called internal ulcer can as well or better be explained as the result than the cause of the stretching of the cornea. Attention has been drawn by Coats to the fact that specimens described as internal ulcers were but tears in Descemet's membrane. It is now accepted in most quarters that the distension of the globe is a result of increased intraocular tension. In its end results the picture

is that of glaucoma, hence it is correct to speak of hydrophthalmus as an infantile glaucoma. Accepting the increased tension as a fact, it becomes necessary to explain how it comes about. The commonly accepted theory of to-day is that there is some hindrance to normal filtration of intraocular fluids, and that such obstruction is usually present at the angle of the anterior chamber.

The obliteration of the spaces of Fontana primarily or the result of inflammation is explanatory of some cases. Anatomical investigations of a few eyes have shown a partial or complete aplasia of the canal of Schlemm (Spielberg). These observations add to the evidence in favor of the retention theory. Mayou reported the finding of the iris pressed against the cornea forming an anterior adhesion virtually all around the pupillary margin, due apparently to a non-separation of the mesoblast of the iris and pupillary membrane from the cornea, which gave rise to a secondary glaucomatous condition and great distension of the cornea. This case is open to doubt as to whether it represents a buphthalmus or an anterior staphyloma. Clinical cases have been observed where undoubtedly an adhesion of the root of the iris was not demonstrable, but the mere presence of a deep anterior chamber in the light of our present knowledge does not argue against an anterior adhesion of the root of the iris. Horner (1889) first called attention to the possibility of some congenital defect in the angle of the anterior chamber being the cause of hydrophthalmus. The theory of hypersecretion applied to hydrophthalmus, adopted by the earlier observers, in much the same way as it was applied in the explanation of adult glaucoma, while still possessing adherents has been much discredited and superceded by the retention theory. Bondi referred to these enlarged eyes as congenital abnormalities which had nothing to do with fœtal inflammation. He likened them to a giant growth of the eye. In this connection Cabannes reported a case associated with hemi-hypertrophy of the face, both conditions due to the presence of a deep-seated subcutaneous angioma. Microscopical examination showed a filtration angle of normal dimensions, Schlemm's canal normal, spaces of Fontana permeable, no adhesion and no trace of uveal inflammation. He gives it as his opinion that the hemi-hypertrophy of the face and the unilateral hydrophthalmus were the result of the same cause, viz., hypernutrition of the neighboring parts.

The question is asked. "Why should not the eye be born larger in the same way as one side of the face, one leg or one thumb, without having to invoke the retention theory or the hypersecretion theory to explain its increased volume?" Hydrophthalmus in about two-thirds of the cases is bilateral and in one-third unilateral. It appears that more

boys than girls are affected. Both eyes show an equal tendency to affection. The condition is often noticed at birth by the obstetrician. Most cases are brought to the attention of the ophthalmologist within the first few years of the life of the child. In those cases developing subsequent to birth there is little room to doubt but that the conditions favorable to its production were congenital. The association with syphilis or the suspicion of syphilis has been frequently remarked by numerous observers. The globe is considerably enlarged, the most prominent thing which attracts attention is the size of the cornea (megalocornea). The cornea may be clear or show a general diffuse haze or opalescence. In other cases the opacities present are circumscribed. The anterior chamber is very deep. The iris may be off color, the finer markings not being apparent. The sclera as a rule is thinned especially in the region of the limbus, though a true staphyloma does not occur. In some few cases a thickening of the sclera is described being attributed to a hyperplasia of tissue resulting from the irritation to which the sclera is subjected.

In shape the cornea is globular or hemispherical. The lens may be abnormally deeply placed or luxated. If this circumstance occurs the iris having lost its support is tremulous (iridodonesis). The size of the lens, as a rule, is rather smaller than normal. Its dislocation is the result of the ocular walls gradually drawing away from it, consequently the zonular fibres become attenuated to such an extent that their rupture occurs. The pupil is usually slightly enlarged, but is sometimes found of normal size, though its response to stimuli is weak and sluggish. As the ocular coats distend those structures, whose nutritional supply are easily upset, viz., cornea and lens, begin to show changes in the nature of opacities. In the earlier cases the lens is generally clear as are also the media. Owing to the ability of the young tissues to stand considerable pressure the retina and choroid do not show early changes. As the process continues, the same results are found as in adult glaucoma. The cupping of the disc occurs and progresses, and optic atrophy eventually supervenes. These eyes are generally myopic but in rather less degree than one would expect from their increased length. The cornea while thinned in all its extent yet suffers more at its periphery than at its center, consequently it may be in a great measure flattened at the center as its stretching is taking place at the sclero-corneal margin. Occasionally emmetropia and even hypermetropia is present. Astigmatism frequently occurs and is with the rule. As would be expected, the vision is greatly reduced in consequence of the ametropia, corneal or lens opacities, and luxation of the lens, if present. In the older cases the vision is destroyed as a

result of the secondary optic atrophy. Associated congenital defects are aniridia, corectopia, coloboma of the iris, posterior lenticonus and hemi-hypertrophy of the face. Weinstein records a case complicated by the presence of a neurofibroma of the lid.

Cyclopia. The presence in the center of the forehead of an apparently single eye has been given the name of cyclopia. The situation of the defect is somewhat above the normal site of the root of the nose. Projecting from directly above the eye is a snout-like projection or proboscis, which from its peculiar appearance has often been misinterpreted as a misplaced penis. There is an enlargement on its end containing an opening which leads into a blind canal. It is a rudimentary nose and at its base contains rudiments of the nasal bones. It is produced by the displacement forwards and upwards of the fronto-nasal processes. The subjects of this trouble are grossly malformed which mercifully tends to an early death, but in unusual cases they have lived for some weeks or months. The condition really represents the fusion of two eyes. It is said to be not so very rare, yet the ophthalmologist finds it so, especially in this country, where the patients dying early are often only seen by the obstetrician and are not brought to the oculist's attention. In animals, particularly pigs, the occurrence is rather frequent. The four lids form a lozenge or rhombic-shaped space. The upper and lower angles are rounded off. The height of the aperture varies, the width generally exceeding the height considerably. The cornea is usually exposed in some of its extent. The lids generally have a normal structure and show cartilage, cilia and Meibomian glands. In the lower angle a caruncle is often formed. The condition of the lachrymal apparatus is variable. There may be present a single canaliculus leading into a short blind sac. In conjunction with cyclopia observations have been made of the following gross anomalies, astomia, exencephaly, hemicephaly, microcephaly, anomalies of the heart and spina-bifida. Various grades of the condition have been observed which for convenience have been divided into the following divisions: The classification is that of Bock. 1. The two eyes exist near together in separate orbits divided by a narrow partition. The nostril is single and very narrow. 2. The two eyes sit so near together, each though in its own orbit, that the rudimentary nose is pushed upwards occupying a position on the front of the forehead. It assumes the form of a snout. 3. One orbit is present containing two eyeballs and two optic nerves. The scleræ are joined together. 4. The optic nerves are closer approximated, the two scleræ are closely fused, forming a thin membrane. The iris, lens, vitreous and retina are double. 5. There is but one cornea. The iris.

choroid, vitreous and retina are double. There are two nerves present separated only by a thin layer of fibrous tissue. 6. There is one cornea, sclera, choroid, retina and optic nerve. The lenses are double but more or less fused together in the middle. This is an arbitrary division and deviations from it naturally occur. To this classification has been added another by Von Hippel in which a single eye is present with no doubling of any structure. (Pennow, Bock, Van Duyse). In Gabrielides' case there was a single eye with apparently no paired structure, but microscopical examination proved that the apparent single lens was in reality made up of two. The size of the cyclopic eye is variable.

Rhinocephalic Cyclopia. (After Van Duyse.)

It is sometimes larger, sometimes of normal size and in quite a number of cases it is smaller even to such an extent as to be designated a microphthalmia. Instances of an apparent anophthalmia also occur, anatomical investigation however, always revealing a rudimentary globe. The presence of the lids, conjunctiva and orbit are indicative of an eye having been formed. The same processes which bring about the production of an ordinary anophthalmia may be likewise responsible for the apparent anophthalmia in cyclopia. Where the two eyes are fused together the point of conjunction is at the place corresponding to the fœtal clefts. At this point particularly there occurs frequently a coloboma of the choroid, retina and optic nerve. Should this become ectatic, a typical colobomatous cyst is formed. Van Duyse has described typical coloboma of the iris and ciliary body and coloboma of the choroid in connection with isolated macular coloboma. The

brain defects are among the most striking of the concomitant conditions; the most frequent among which may be mentioned absence of the olfactory lobes and chiasm, absence of the corpus callosum, trigonum, and corpus striatum. Brain structures may be fused, notably the two hemispheres together and the two thalami together. The optic nerve is at times missing in which event the retinal nerve fibres and ganglion cells are deficient. The formation of the common orbit is produced by the disappearance of the ethmoid, by which the two cavities are thrown into one. The lamina cribrosa is present but contains no perforations. The crista galli is absent. The orbicularis is double, it being doubtful if it is ever single. It is difficult to conceive how it could be so. The extrinsic muscles are double but so badly developed and matted together as to be isolated with difficulty.

The genesis of the defect has been the subject of discussion. It is even yet not quite clear and settled. It has been experimentally produced in fish embryos. Stockard, who has followed this line of investigation, compares the results of his experiments with mammalian cyclopean monsters. He states as follows: "These embryos throw interesting light on the development of the crystalline lens. In many of them a lens forms from the ectoderm and differentiates independently of the influence of an optic cup. Some embryos with one lateral eye and the other wanting have a perfect lens on the eyeless side. The lens lies freely in mesenchymous tissue and is disconnected entirely from any portion of the nervous system." He further states that "experiments now show that cyclopean fish embryos may be produced by the action of two salts of magnesium in sea water solutions. The embryos exhibit various conditions of the cyclopean defect from the earliest appearance of the optic vesicles. Cyclopia is not due to a subsequent union or fusion of the two eye elements after their free and distinct origin." Lewis experimented on the eggs of *fundulus heteroclitus* during the embryonic shield stage by thrusting a fine needle through the egg membrane into the anterior end of the shield. Some of the material was expressed by slight pressure and the parts left behind closed rapidly and the wound healed without regeneration of the lost parts. Rudiments by these means were brought into contact that normally are widely separated. The cyclopean forms are explained through a fusion of the rudiments of the two eyes immediately after the operation, even though at this time no rudiments are visible. He draws the following conclusion: "The cyclopia in man can be explained through the influence of external factors acting during early stages of development in such a manner as to produce a single eye rudiment and we need not seek for a germinal explanation. It

seems likely that in man similar early fusion of the eye rudiments must take place to produce cyclopia. These experiments throw no light of course on the cause of the early defect in man although Stockard's experiments indicate that chemical factors might be responsible for such defective or altered early development.''

One of the older theories is that of Huschke. It is quoted here chiefly for its historical interest. The later developments in embryology have clearly disproved the fundamental basis of his contention. He held that in the early fœtal development the primary optic vesicles existed as one in that part of the anterior cerebral vesicle which later on becomes differentiated into the two primitive optic structures and that through some defect or failure of development the normal process of division did not take place. The failure of one optic vesicle to develop would not result in cyclopia for as Von Hippel points out such an occurrence would easily account for anophthalmia, but the monophthalmic eye would be on the side to which it belongs. The mesial position of the cylopic eye cannot therefore be reconciled with the supposition of a single optic vesicle evagination. Nor would the destruction of one vesicle very early in the development tend to a cyclopic formation for the same reason. It is well known that the most profound effects are the result of the earliest influences bearing on those tissues involved, hence the earlier the fusion of organs or parts of organs occurs, the more perfect and complete will that fusion be. This is clinically borne out by the numerous divisions of cyclopia made by Bock. The most perfect forms of cyclopia where apparently all structures are normal show however, on microscopical examination that the existing lens is in reality a fusion of the two lenses. Such cases as these must represent a very early fusion of the primitive ocular structure. It is easy to assume that cyclopia is the result of an early fusion but to satisfactorily explain the modus operandi of the process, is rather difficult. Yet fusion by whatever means it is brought about looks like the most reasonable hypothesis bearing on cyclopia. Dareste during teratological experiments frequently noted cyclopia.. He noted that early in the development at the anterior end of the central nervous system, there exists a perpendicular cleft which remains open up to a certain stage of development of the optic vesicles. Should this cleft close at too early a period, a pernicious influence is exerted on the development of the vesicles. At the beginning of the budding of the optic vesicles, they lie almost diametrically opposite one another. A destruction of the intervening tissue from whatever action might cause them to be brought into contact and fuse. Whether pressure of the amnion can bring about this effect or cause the too early closure of

the vertical anterior cleft as supposed by Dareste is an unsettled question. Van Duyse and Taranetsky accepted the theory of amniotic pressure as an etioligical factor. To attribute cyclopia to absence of the ethmoid (Dursy and Ahlfeld) or to the destruction or displacement of intermediate parts (Panum), would appear a reversal of the actual conditions. The eye development is early, that of the bony parts is later, therefore the nasal and the other bony deformities are the result of the cyclopia and not the cause.

It can be assumed that where the early fusing of a primary optic structure has occurred the resulting vesicle may be invaginated by two directly adjacent lenticular processes of ectoderm. As a result of further growth these two masses become joined and give rise later to the apparently single lens. In this way are explained the findings of Gabrielides. It can also be assumed that the early completely fused primary membrane may be invaginated by a single protuberance of the ectodermal cells with a single lens resulting. Von Hippel is inclined to this view as explanatory of the cases of Peunow, Bock, and Van Duyse in preference to the acceptance of the theory of early destruction of one primary vesicle with the other remaining and developing into a clyclopia. That a cyclopia can occur through the consolidation of two previously separated eye elements is shown by the existence of monster formations represented by the diprosopus class. In the diprosopus triophthalmus the heterologous halves of the face are fused. The accompanying eyes more or less fused occur in the middle of the fused face and give rise to the varying grades of cyclopic formation.

Seefelder concludes that in cyclopic eyes there is a very early fusion of a cell mass not yet differentiated into definite organs. He reported four cases in a contribution bearing on the pathology and pathogenesis of cyclopia. One of the cases belonged to the Janus group of cephalothoracopagus and showed in a cyclopic eye two normally developed lenses and their vessel systems. He quotes Marchand to the effect that cephalothoracopagus has its origin in an early blending of two originally separated embryonal rudiments upon one germinal vesicle. The union takes place on the abdominal side—the forehead side. On the normally developed side of the face the two eyes develop from two different embryonal rudiments. The same is the case with the cyclopic eye on the defective side of the face. In this cephalothoracopagus case the cyclopic eye showed besides the two normally developed lenses, the entire retina plicated. There were enclosures of the retina in the optic nerve, a funnel-shaped excavation in the position of the optic nerve entrance, absence of nerve fibres in the optic nerve and retina. Another of his cases was one of diprosopus triophthalmus. The fusion

of the two relatively well-developed eyes had taken place to the side and was limited to the sclera and ciliary muscle. There was no coloboma. The optic nerve and retina did not contain a trace of nerve fibre.

Persistent pupillary membrane. The persistence of part of the pupillary membrane while not an uncommon condition is relatively rare. Statistics vary widely as shown by the reports of Mooren 14 in 100,000, Uthoff 6 in 10,000, Königstein 21 in 3,000 patients, Schleich 13 in 150, Franke 32 in 3,508, Stephenson vestiges in 68 out of 3,414. Such a variation is no doubt due to the strictness of classification of

Persistent Pupillary Membrane.

The minute strands may be seen to originate in and to be attached to the *circulus arteriosus-iridis minor.* (Greeff.)

different authors. Where the merest vestiges are recorded the ratio will of necessity run higher. The pupillary membrane being a structure normal to fœtal life, it is not surprising that the ratio of positive finding runs high in newborn children, and this coupled with the fact that in later life the ratio is lower, inevitably leads one to conclude that the pupillary membrane may disappear not before, but some time after birth. In the latter part of the second month the optic vesicle is differentiated into the anterior or iridic part, a middle or ciliary part, and a posterior or retinal part. It is in the iridic or anterior part that the changes relative to the present subject take place. The anterior chamber is formed not as often supposed between the iris

and the cornea but between the cornea and the vasculo-pupillary membrane. The mesoblastic tissue growing in from all sides in the anterior part of the eye, causes the thin iridic segment of the optic vesicle to bend over the equator of the lens and develop inwards towards the pupillary region. This mesoblast, the forerunner of the iris stroma, thus carries upon its posterior surface the iridic portion of the optic cup, their development going forward hand in hand. The stroma of the iris, the pupillary membrane and the cornea, are all mesoblastic tissues. The lens early formed is at first in contact with the cornea, but becomes separated from it by the differentiation of the pupillary membrane and iris stroma. By the fourth month the iris is formed

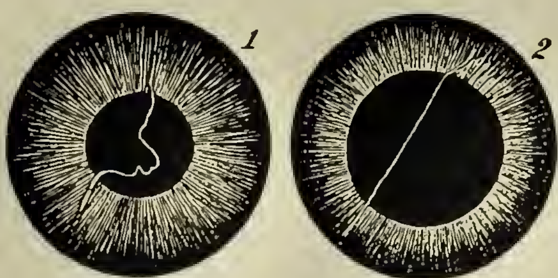
Persistent Capsulo-Pupillary Membrane and Hyaloid Artery. (After Stephenson.)

and the anterior chamber is lined with endothelium. The pupillary membrane persists until the seventh month, at which time it begins to be absorbed and at birth it should have completely disappeared. The anterior vascular sheath has a vascular connection with the posterior lens sheath, but in all other respects they are distinct structures: hence one may disappear while the other persists. As usually observed the persistent pupillary membrane varies in color, in extent and in its relation to surrounding parts. Persistent remains are distinguished from posterior synechiæ by their taking origin from the anterior surface of the iris usually in the region of the smaller circle, never from the pupillary margin and frequently much farther peripherally than the smaller circle. The latter fibres may even spring from the ciliary border of the iris, join together with their ends falling free in the pupillary area, or matting together into a sort of net work from a central plaque of light color. This plaque may exist free in front of the lens capsule or be adherent to it. The pupillary fibres are generally considerably lighter than the iris, but often in their color and

whole appearance they resemble the iris stroma. The movements of the iris behind the persistent membrane as a rule are unimpeded. The lens is normal and clear except in a few instances where pyramidal cataract has been observed. Occasionally a central group of fine brown dots is seen upon the lens capsule. The condition is more often met with unilaterally. Very seldom is a simultaneous persistence of the posterior vascular capsule seen. Instances of

Persistent Capsulo-Pupillary Membrane in Both Eyes. (After Massey.) (*Ophthalmoscope,* Nov., 1908.)

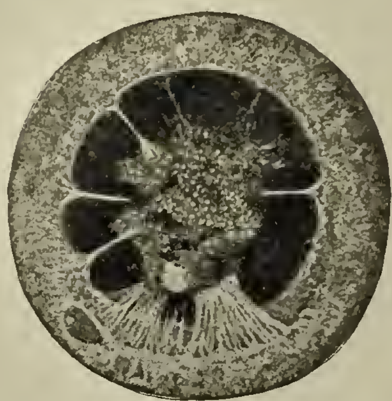
this are recorded by Mayerhausen, Franke and Berger. The arrangement of the fibres varies in different cases and shows changes in tenseness or laxity with dilatation or contraction of the pupil. The fibres have been seen disposed in the following manner: First, several fibres arising from the small circle at different points in its circum-



Persisting Pupillary Membrane: (1) Pupil contracted; (2) Pupil dilated. (Wickerkiewicz.)

ference, stretch across the pupil from a delicate network in front of it. Second, Fibres run tangentially between two points in the small circle of the iris. Third, all the toothed projections of the small circle are prolonged inward and project beyond the pupillary margin. Fourth, one or more fibres attached to the small circle of the iris, float free at their other extremities. Fifth, a loop is formed by two fibres

in front of the pupil. Sixth, one or more fibres arise from the iris and are attached to the lens capsule. Seventh, a fibre extends from the iris to the posterior corneal surface. Eighth, fibres unite in the pupillary region from a net work more or less dense constituting a plaque, attached or unattached to the lens capsule. In the plaque formations the taut threads may give the appearance of turning the pupillary margin backwards, something after the fashion of so-called iris bombé (Massey). Plaques are often slightly pigmented. The fibres vary greatly in thickness, some being so fine as only to be detected with magnification. They are extensile. Very thin blood vessels are found in persistent membranes, and these are almost always empty, blood corpuscles having been present only in a few instances. The central



Persistent Pupillary Membrane. (After Levy.)

plaques are made up of a finely granular connective tissue with oval and spindle-form nuclei. The anterior and posterior surfaces are covered with an incomplete endothelial layer. The vessels lie posteriorly and consist of endothelial tubes. The pigment spots are brown and round or spindle-shaped. The threads themselves consist of firm connective tissue between the fibres of which are long, flat or spindle cells, leucocytes and pigment cells. The threads are continued direct into the iris stroma from which they differ very little in their histological structure. Crystals of hæmatoidin were found by Meyerhausen in the rabbit in the tissue overlying the anterior lens capsule. The main difference between normal and persistent pupillary membrane is in the excessive density of the latter and in its abnormal pigmentation (Von Hippel).

Disturbance of vision as a rule is not observed except in those cases of a dense central plaque in which the disturbance may be so great as to necessitate operative interference. By this means most of the specimens have been obtained for histological examination (Graefe, Colin, Hasner, Wicherkiewicz, Van Duyse, Rumschewitsch). The fre-

quent association of astigmatism has been noted but it is difficult to positively say if there is any close relation between the two conditions.

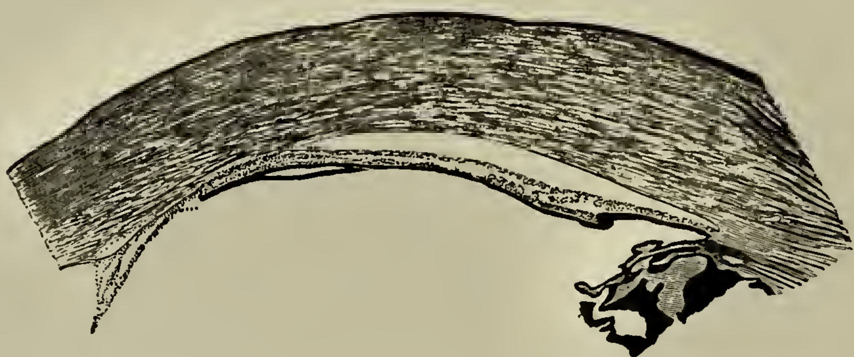
In explanation of the genesis of persistent pupillary membrane, Michel elaborated a very intricate theory. He thought that regularly in the development at the sixth month, a peripherally situated fold is formed in the iris with its concavity forwards. At this place the endothelial surfaces of the pupillary membrane are fused. Due to the growth of the anterior chamber traction is made resulting in a thinning and atrophy of the central part of the membrane and a pupil is formed. Persistent pupillary membrane he explained the following way. A separation of the fused surfaces does not occur, and that as a result of traction and counter-traction holes form in the parts lying centrally. Also, one must accept further that a decided firmness or solidity of the pupillary membrane is present. This hypothesis is conspicuous by its lack of lucidity. Abnormal density of the pupillary membrane as seen clinically and anatomically is the probable cause of its incomplete absorption but what the cause of the increased density is not known. It may be due to an atypical development of connective tissue or the result of an inflammatory process in the anterior segment of the globe. In support of this latter are the instances of adhesion of the central plaque to the anterior lens capsule and of abnormal pigmentation of the central part of the lens capsule and the central plaque. These changes need not, however, be inflammatory, the adhesion being easily explained as due to failure of separation, and the pigment as being deposited post-natally, for as is known the pigment in the stroma of the uveal tract is nearly all laid down after birth.

Schubert proved that the occurrence of exceedingly small dots of pigment on the lens capsule is so frequent that acceptance of an inflammatory cause for them is impossible. Furthermore the suggestion of Meyerhausen that by the gradual obliteration of the vessels some blood is left behind which deposits hæmatoidin, is worthy of consideration.

Anterior synechiæ of iris and persistent pupillary membrane. Cases have been described by Beck, Samelsohn, Macrocki, Wintersteiner, Zinn, Collins, Silcock, Wüstefeld, Van Duyse, von Hippel, and Ballantyne. In many of the cases related by observers there has been the possibility that the adhesion was caused by intra-uterine perforation of the cornea. Beck described a case in a 20-year old man in whom a central capsular cataract was present. On the corresponding part of Descemet's membrane was an opacity, and others at a lower level. From the upper opacity a blood vessel traversed the anterior

chamber to the upper margin of the pupil, and at the middle of its course divided into five branches which entered the iris in the region of the minor circle. Beck took this to be a congenital anomaly, but Arlt thought that as the patient had had ophthalmia neonatorum, there had been a perforating ulcer of the cornea, which left a corneal cicatrix and a deposit on the capsule; the vessel he took to be a synechia between the capsule and the cornea. There are doubtless cases of true congenital anterior synechia of the pupillary membrane as the fibers spring from the lesser circle and pupillary membrane remains are frequently present in the other eye.

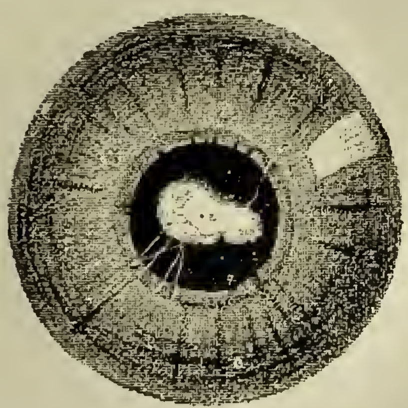
Referring back to the development, it is seen that the anterior fibro-vascular sheath of the lens and the pupillary membrane are developed from the posterior part of the mesoblast which grows in to separate the lens from the ectoderm, the anterior part forming the substantia



Congenital Anterior Synechia. (Treacher Collins.)

propria of the cornea. It is conceivable that occasionally the anterior fibro-vascular sheath, in a part of its extent at least, might fail to separate from the cornea, with the result that anterior synechiæ of the pupillary membrane are formed. Macrocki, Vossius, Collins, Wüstefeld and Rumschewitsch supported this theory. Rumschewitsch in a later article said that he had been led to believe by his previous observations and those of others that the persistence of the pupillary membrane should be looked upon as a consequence of the abnormal development of the membrane during embryonal life. If in such cases the membrane followed the type of the iris in its development it would be unable to atrophy in the way the normal embryonal pupillary membrane does. Therefore, we have not to do with a persistence but with an abnormal development of this membrane. To inflammation with or without perforation of the cornea, has been ascribed the origin of this anomaly by Samelsohn, Van Duyse, and Wintersteiner. Von Hippel is favorable to the theory that inflammation or perforation

of the cornea during embryonal life, resulting in a temporary abolition of the anterior chamber, and an adhesion of the pupillary membrane to the cornea, is the cause of anterior pupillary membrane synechiæ. Only in the cases of Macrocki and Vossius, of those above mentioned, was nothing found indicative of a pre-natal or post-natal inflammation. Without doubt this condition may arise from the perforation of an ulcer. In a considerable number of the recorded cases there has been a history of ophthalmia neonatorum. In Wintersteiner's case the membrane was actually seen microscopically entangled in a recent perforation. The pupillary membrane may not disappear until after birth; hence if a perforating ulcer occurs shortly after birth, it may prolapse and become incarcerated in the cicatrix. Even then it would probably disappear in most cases in the usual manner; but in some instances the vascular demands of the



Pupillary Membrane Adherent to the Cornea. (After Van Duyse.)

healing ulcer, and communication of the vessels of the membrane with those of the cicatrix, may cause its persistence (Coats). This does not, however, explain all cases, for in many no history of ophthalmia neonatorum or other cause of ulceration was present (Macrocki, Zirm, Traltner, Vossius, Wüstefeld), and where the cornea was clear, except for a minute opacity in the deeper layers at the point of insertion of the membrane. That the condition is a result of a fœtal kerato-iritis is improbable. Treacher Collins found the condition associated with persistent hyaloid artery, the cornea being clear and microscopically normal. Von Hippel found it in a microphthalmic eye along with many other abnormalities; where the strand was inserted, Descemet's membrane was absent.

The findings of these two authors point to the occurrence of the condition as a true malformation. Congenital anterior synechiæ of the pupillary membrane may, therefore arise in two ways; either as a

pure malformation, or from perforation of a corneal ulcer. This anomaly is seen in the form of a variable number of pigmental threads, taking origin frequently by many radicals, from the region of the lesser circle. They pass across the anterior chamber to be inserted into the cornea. In their course before reaching the cornea the fibers may break up into a number of branches. Where they are inserted at the cornea there is a gray or whitish, deep-seated, dotted opacity. The fibers may all be inserted into a single corneal plaque, or a more diffused nebula. Anterior polar cataract is at times present. The anterior chamber is of normal depth, and the movements of the pupil are not interfered with. When the pupil is contracted the fibers hang loose in the anterior chamber, but when dilated the threads are rendered taut.

Aniridia. Aniridia is a condition of apparent complete absence of the iris. As a rule, however, tags or remnants or iris tissue are pres-

Aniridia. (Treacher Collins, *T. O. S. U. K.*, XIII.)

Anterior part of eye with apparent aniridia. The cornea and sclerotic have been removed, exposing a rudimentary iris, tags of pupillary membrane, lens with an anterior capsular opacity, and fibres of the suspensory ligament.

ent, but escape detection clinically. It may be looked upon as a total coloboma of the iris. Almost without exception it is a bilateral condition. Unilateral cases have been reported by Brunhuber and Tokkus. A complete aniridia may exist in one eye, the other showing an incomplete absence (Gutfreund). Total aniridia of one eye and a large coloboma of the other may occur simultaneously (Rindfleisch-Foster). Quite a number of clinically incomplete cases have been observed and the term incomplete aniridia should be reserved for such cases. To be exact, complete absence never occurs, anatomical investigation always revealing stumps or tags of iris tissue. However, it is proper to speak of such cases as complete where clinically no iris can be detected. On inspection the appearance of an aniridic eye is

striking, peculiar and characteristic. Where the iris should be there is, as in the normal pupil, nothing but blackness. The blackness of the pupil is more apparent than real for on close inspection even with a clear lens a grayish reflex is seen. On facing the light or upon examination with the ophthalmoscope a large red reflex is obtained broken at its border by a circular dark line, the margin of the lens. Beyond the edge of the lens a fine striation, the fibers of the suspensory ligament, may be detected. The facial aspect of the patient is somewhat characteristic due to the efforts to shut out the light, and also because of the numerous complications frequently present. Photophobia is present, and palpebral fissure is often voluntarily narrowed, and the brow corrugated in the effort to escape the excess of light. Nystagmus occurs as a frequent complication, less frequently strabismus is observed. The explanation of the nystagmus is given by Seefelder who made an anatomical examination of an aniridic eye. He directs attention especially to the change found in the posterior segment of this eye since most all previous examinations have been deficient in this respect. Failure of differentiation of the retina in the macular region was found and this is of great importance as it provides an explanation for the well-known nystagmus and amblyopia in aniridia. Aniridia, amblyopia and nystagmus form a hereditary triad. Coincident anomalies are frequent, the cornea shows anomalies in regard to its form and transparency, frequently it is of a horizontally oval form (von Hippel), or there may be conical cornea, opacities of the cornea, embryotoxon, microcornea and small bilateral symmetrically placed depressions of the corneal surface in the inner quadrants (Rindfleisch). It is impossible always to say if corneal opacities are congenital or acquired. Other complications at times seen are vitreous opacities, atrophic choroidal spots and detached retina, but whether these are concomitant defects or subsequent lesions the result of inflammatory or other causes one is unable always to state with certainty.

The anterior chamber is generally of normal depth, sometimes of abnormal depth and very rarely is it shallow or absent. The lens shows the most frequent complications, the opacities being partly congenital and partly acquired. The commonest changes are anterior and posterior polar cataract. Less frequently posterior cortical opacities and lamellar cataract are observed. Partial cataract may in rare instances clear up of itself. Operative procedures should be undertaken with great caution in these cataracts as they are liable to be followed by a severe lingering inflammation. Another common complication is dislocation of the lens, usually upwards. This may

be present at birth or develop later. Hirschberg positively established the possibility of both opacities and luxation taking place in later years. Partial or complete absence of the suspensory ligament at times occurs. In the majority of cases the ciliary processes are not visible, but from this it cannot be inferred that they are absent.

Seefelder (v. Graefe's *Archiv für Ophthal.*, 70, 1, 1909) examined an eyeball in which the iris was congenitally absent. The cornea had been steamy and opaque, and its sensibility diminished; there was nystagmus, and some lenticular opacity. The dimensions of the eyeball were abnormally large; the lens was small, and the circumlental space broad. On opening the eyeball it was noticed that there was no retinal pit at the foveal site and there was an absence of the usual pigmentation of that region.

Microscopically, very little change was found in the cornea to account for the appearance of opacity. The iris was at no point entirely absent but was represented by a short stump varying in length from 0·75 to 0·32 mm. The iris rudiment was shortest at the nasal side, where there could scarcely be said to be any actual iris. It passed backwards into the tissue of the ciliary body and forward to the termination of Descemet's membrane. It lay closely applied to the sclera at its junction with the cornea, and completely cut off the canal of Schlemm from the anterior chamber. The so-called angle of the anterior chamber was obliterated.

At the temporal side the iris rudiment was longer and had the situation of the normal iris. The angle of the chamber was free, but here also there were fine forward prolongations of the iris tissue applied closely to the sclera. The iris rudiment consisted of richly pigmented stroma and pigment epithelium. There was no trace of a sphincter or dilator muscle. The ciliary processes were poorly developed.

In the cases examined by Rindfleisch and Lembeck, the processes were well developed. A deficiency in the ciliary development might well be the origin of a zonular defect. One office of the ciliary processes is to generate aqueous fluid and the ciliary muscle to govern accommodation. The presence of aqueous and the intactness of accommodation speak for the presence of the ciliary apparatus. Other complications are ptosis, microphthalmus, persistent hyaloid artery, persistent pupillary membrane and hydrophthalmus. Glaucoma as a secondary complication is not uncommon (Collins, Brailey, de Schweinitz, Dennis). To the ectopia lentis usually present may perhaps be ascribed the secondary glaucoma. In Dennis' case the glaucoma was not spontaneous but followed a cataract extraction. Here there was total aniridia, complete absence of ciliary bodies and no

ectopia lentis. The absence of the ciliary body is in opposition to the view that the usual glaucoma in aniridia is due to the pushing forward of the rudimentary iris into the ciliary angle, thus obstructing drainage. An interesting point noticed by Dennis and previously mentioned by Scalinci was the fact that the use of eserin invariably reduced tension. It has heretofore been thought that the lowering of tension of the eye following the use of eserin was a direct result of the miosis. The absence of iris to contract and the absence of ciliary processes to produce aqueous in this instance at least throw a new light on the mode of action of miotics. Dennis suggests that tension is probably lowered by reason of the well-known power of eserin to contract the blood vessels.

The sight of aniridic patients is usually much reduced. The history is that they never saw well from childhood on. The immoderate amount of light must produce a dazzling and lack of definition; furthermore if it be true that the macula is mal-developed, there are ample reasons for amblyopia regardless of the usual complications. How much the aniridia *per se* reduces vision it is impossible to say. The usual complications are in themselves sufficient to greatly reduce vision.

Valois (*L'Ophtalmolgie provinciale*, January, 1908) records a case in which a patient with congenital absence of the iris suffered from cataract. He found that as the lens became more opaque his usual photophobia and day blindness became less, but, unfortunately of course, vision at the same time failed progressively. After extraction vision again was good, but the day blindness was as bad as ever. In order to give relief to this condition, and allow the patient to use his eye, Valois found that a plate of copper with a cross cut in it was a satisfactory appliance. This was attached to the plane surface of his plano-convex lens (+11D) in such way that it could be removed for the purpose of cleaning the lens. This gave the necessary protection and the patient enjoyed excellent vision and relief from photophobia. The hint might prove useful in other circumstances also.

In another case reported by Wernicke the eyes of a boy, 12 years old, were defective from his birth, according to his mother, but is otherwise healthy and presents no other anomaly except horizontal nystagmus. The intraocular changes are almost equal in both eyes, which attract attention by their dark color, not allowing either the iris or the pupil to be perceived by oblique illumination. The cornea is transparent, except in an opaque zone, 2 millimeters in width, around the limbus; the anterior chamber is normal; no signs of iris are seen. The crystalline lenses, irregularly circular, are dislocated upwards, their upper edges touching the limbus, with a zone of aphakia, 3 milli-

meters in width, downwards. Both lenses show at the periphery opaque grooves, and on the posterior cortex large white spots. Neither the zonulæ nor the ciliary bodies are visible. The fundi are normal. Distant vision is reduced to counting fingers; near vision, R. E. Wecker No. 5, to 8 centimeters; L. E. Wecker No. 4, to 6 centimeters.

The author proposes tattooing as a remedy for the photophobia, when the lenses have been successfully extracted; or in cases where they are transparent.

Some patients complain of no symptoms yet the best vision probably recorded was that in Talko's case, where in spite of anterior and posterior cataract, the vision varied from 1/3 to 1/2. The accommodation as a rule is in no way affected. Anatomical examinations have been made by Radius, Pagenstecher, de Benedetti, Lembeck, Rindfleisch, Collins, Hopf, E. H. Pagenstecher, Bergmeister, Van Duyse and Seefelder. In all, with the exception of Hopf's case, a remnant

Aniridia. (Treacher Collins, *T. O. S. U. K.*, XIII.)

A persistent tag of pupillary membrane is attached to the tip of the rudimentary iris, and there is a peripheral anterior synechia.

or stump of iris tissue was present of variable width lying free in the anterior chamber or adherent to the back of the cornea. The sphincter, if present at all, is exceedingly rudimentary. Deposits of pigment around Schlemm's canal or on the back of the cornea have been found. In Seefelder's case the iris rudiment on the nasal side passed backwards into the tissue of the ciliary body and forward to the termination of Descemet's membrane. It was closely applied to the sclera at its junction with the cornea and completely cut off Schlemm's canal from the anterior chamber. There was no real angle at this point. This tissue he takes to be the remains of a structure which occupies the angle of the anterior chamber in the fœtus and disappears when the iris becomes developed. Its presence explains the frequent occurrence of glaucoma in aniridic eyes. Van Duyse found the following changes in a case of incomplete aniridia. 1. Fontana's space was large and the ligamentum pectinatum iridis was greatly hypertrophied as it appears in a fœtus from 7 to 9 months, and in many mammals. 2. Absence of the sphincter and dilator pupillæ. As these muscles begin at the fourth month the cause of the aniridia must be present before

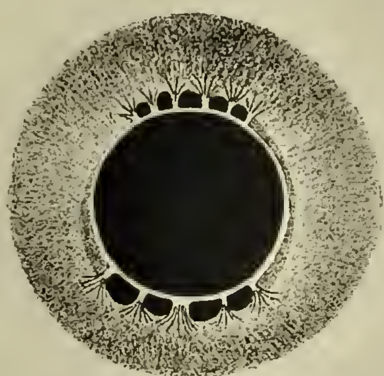
this developmental epoch. 3. Degeneration of the vessels of the uveal tract. The last explains the unfavorable prognosis of glaucoma in aniridia. In this anomaly the influence of heredity is most strikingly seen. Possibly in no other anomaly of the eye is it more evident. A classical example is that of De Beck with seven cases of aniridia and two colobomata in three generations. Gutbier found ten cases in four generations; Galezowski thirty-one cases in three generations; Mohr. a mother with complete, and two sons with partial; Gutfreund, a father and daughter with complete aniridia; Hamilton, a father and three sons; Despagnet, thirty-one members in one family. Excluding those just mentioned, there are a number recorded in the literature which for convenience are classified as follows: direct hereditary, 18 mothers to 31 children, 10 fathers to 19 children, and 7 showing collateral heredity.

Partial Aniridia. (After Rindfleisch.)

The explanation of aniridia has been the subject of many theories. No less than 15 have been urged by their authors. That it represents a congenital defect of development, and not a destruction due to intrauterine inflammation is almost beyond question. Arnold was of the opinion that the absence of the anterior ciliary vessels was the cause of the nondevelopment of the iris, but as von Hippel points out this is anatomically unproved and not acceptable as these vessels are for the supply of the anterior vascular sheath of the lens. Sichel considered the condition as a congenital mydriasis; but this is of historical interest only. Manz believed the cause to be an abnormal contact of the lens with the cornea in point of time, whereby the growth of the iris inwards was mechanically impossible. In support of this were the observations in which the lens was pushed forward and the anterior chamber eliminated, as were also the frequent occurrences of corneal opacities and zonular defects. Rindfleisch believed that a

fœtal inflammation led to a perforation of the sclera at the limbus, with the consequent opening of the anterior chamber and loss of the aqueous whereby the lens was pushed forward in contact with the cornea and held there by an inflammatory exudate. It is conceivable according to the Rindfleisch theory that this abnormal inflammatory adhesion could persist long enough to prevent the ingrowth of the iris and yet later due to the closure of the perforation with cicatricial tissue, the reformation of the anterior chamber could occur with the resumption by the lens of its normal position. The final absorption of the inflammatory exudate would leave no trace other than the prevention of growth of the iris. Von Hippel objects to both of the hypotheses on the ground that the iris is of late development and that such adhesions would prevent the proper development of the substantia propria of the cornea. Another strong point against the Rindfleisch theory is that aniridia is almost without exception bilateral. A bilateral inflammation with perforation and results so nearly alike on both sides is to say the least highly improbable. To invoke a perforation in order to explain contact of lens and cornea is unnecessary as these structures in early fœtal life are already in contact, the anterior fibro-vascular sheath alone intervening. Whatever explanation is acceptable for atypical iris coloboma can be equally well used to explain aniridia, for the same cause acting simultaneously around the whole circle will do so. The theory then of Hess as applied to atypical coloboma of the iris and supported by Coats must receive consideration. In this theory cognizance is taken of the fact that mesodermic tissue passes forward normally around the equator of the lens to join the anterior mesodermal ingrowth, not only in the region of the fœtal cleft but in all directions. Its presence is normal and it gives way to the iris as the iris grows in from all sides, its presence is not inhibitory except when it is hyperdeveloped or over-vascularized. Should but a strand be thus affected a coloboma is formed; if the whole tissue is concerned, aniridia results. The researches of Coats tended strongly to support this last hypothesis. He points to a structural peculiarity of the iris stump, which is common in cases of coloboma and aniridia, and which supports the Hess theory, the same being a backward folding of the iris mesoblast round the termination of the optic vesicle best explained as being either a persistent portion of a strand from the fibro-vascular sheath, or as the result of retraction of the iris stroma by a strand of this kind which has since disappeared. The theory of Hess applies equally well to aniridia, partial aniridia, typical and atypical coloboma, which are in reality gradations of a common trouble. Manz' theory of aniridia on the other hand is not applicable to coloboma, for

while a localized contact of lens and cornea could prevent a portion of the iris from developing, the general application of this theory would exclude the influence of the fœtal cleft and fail to explain the frequent association of typical iris coloboma, with typical choroidal coloboma. Another explanation of aniridia is that of non-differentiation. According to this the mesoblast fails to properly separate into cornea and iris, so that the iris never being differentiated cannot grow inwards. Treacher Collins thought that the fibro-vascular sheath remains adherent to the anterior lens capsule and thus prevents the ingrowth of the iris. It will be seen that with the exception of the intra-uterine inflammatory theory, all those which are worthy of serious consideration invoke an obstacle to the ingrowth of the lens from the periphery, which takes place normally at the fourth month. One point in favor of the inflammatory theory is the existence of



Polycoria (9 additional pupils). (After Rumschewitsch.)

aniridia in one eye, and adherent leucoma in the other (Vossius). The occurrence of unilateral aniridia is so rare that these findings may well be considered coincidental.

Polycoria. The name polycoria designates a condition characterized by a multiplicity of iris openings. Usually there is but one extra opening, but as many as nine or ten and even more have been observed. But one opening, the true pupil, has a sphincter muscle; in the instances where clinically a widening or narrowing by the use of mydriatics or miotics was brought about, such movements were due to the changes in the shape of the true pupil and the adjacent iris, and not to the presence of accessory sphincters. The name polycoria is limited to actual holes in the iris. The division of the pupil by bands of persistent pupillary membrane and bridge colobomata are therefore excluded. Very rarely are two pupils of equal size seen. Rumschewitsch records a case showing eleven openings and von Hippel one with sixteen. Cases of polycoria have been divided into four separate

and distinct classes by Lang and Collins in Norris and Oliver's *System*. Two of these classes, viz., those with persistent pupillary membrane and those of bridge coloboma are not cases of polycoria. Franke defines two groups. 1. Rounded or slit-like holes near the pupillary margin. 2. Openings at the ciliary border resembling iridodialysis or colobomata. The latter division might well be designated congenital iridodialysis. A peculiar variety was described by Mittendorf occurring in a father and daughter. In a single eye of one of them were five pupils, a normal oval central one and four others at the periphery of the iris, cone-shaped, with their bases at the margin of the cornea. In the other patient one eye had a central pupil and at the periphery below was a large opening divided into two by a thin, vertical band of tissue. Polycoria has been observed in one eye, while the other showed a typical coloboma of the iris (Schapringer). Other congenital anomalies observed are corneal opacities, posterior cortical cataract and coloboma of the choroid. Talko's case showed numerous posterior

Diplocoria. (After Weingenroth.)

synechiæ; and Treacher Collins speaks of minute anterior synechiæ being found. Here may be mentioned a case of anomalous iris reported by Polte. A 13-year-old child showed opacities of the left cornea, the iris was normal except the lower portion extending from the pupil to the ciliary border, which was thin and atrophic. At the lower outer border of this portion there was a hole 1½ mm. long through which the fundus reflex could be gotten. The upper part of the hole was covered with numerous fine, transverse, brownish fibers. At the lower inner margin of the hole the iris was thickened and from this point numerous fine threads passed through the anterior chamber to the posterior surface of the cornea to which they were attached. The pupil was displaced downward and rotary nystagmus was present. The first group were considered by Manz to be due to defective development of the mesoblast, and by Rumschewitsch to improper fusion of the retinal and mesoblastic layers of the iris. The probable explana-

tion of the second group is an intra-uterine inflammation. This is more especially so in those cases with anterior or posterior synechiæ. Polte's case was doubtless an inflammatory one. Other causes assigned are proliferations at the pupillary border (von Ammon), and intra-uterine or intra-partum trauma.

Abnormalities of the pupil. The pupil may show a number and variety of congenital abnormalities in regard to shape, size, position and number. When altered in position it is called corectopia; when in size, microcoria if small, macrocoria if large; when in shape, discoria; and when the number of openings is increased, polycoria. Corectopia and polycoria are considered under separate headings. Microcoria is occasionally seen where it is not the result of adhesions due to a fœtal iritis. In such case it is generally associated with corectopia. Associated with congenital cataract a small immobile pupil is frequently seen which does not dilate well even when a mydriatic is

Polycoria. (After De Schweinitz.)

used. Faulty shape, or discoria, where no tissue has been lost and the iris is intact, is met with both as a result of fœtal iritis and also when no inflammation has taken place. At times the distortion is produced by the pull of a strand of persistent pupillary membrane, giving the margin of the pupil a toothed appearance, and the pupil itself a star-shape.

Slit-like pupils. This extremely rare anomaly has been described by Greeff (*Archiv f. Augenheilk.*, 1913) by Fehr (*Berlin Ophthalm. Gesellschaft*, Feb. 23, 1899) and Bürsteubinder in the (*Klin. Monatsbl.* 1902).

In one of Greeff's cases the right pupil was a vertical slit running rather obliquely from above nasally downwards and outwards.

The left pupil was a vertical slit rather towards the temporal side of the globe. The reactions of the pupil were very poor, on the right side due no doubt to the corneal opacity.

In none of these cases was there any evidence of past iritis, and there were no posterior synechiæ.

Fehr pointed out that the condition of the pupil was exactly similar

to that of the cat, the sphincter pupillæ does not form a ring round the pupil, but becomes a long strand attached at each end to the ciliary region.

Bürstenbinder considered his case one of a typical coloboma of the iris.

Greeff is unable to agree with this view; in his opinion the condition is a form of atavism in the Darwin sense.

He points out that this stenopæic pupil is not to be looked upon as an attempt by nature to overcome high degrees of astigmatism, and cites the well known fact that the eye of the cat which shows this slit-like pupil in light adaptation is rarely at all astigmatic, and that in the dark slit-like pupils in lower animals and in human beings tend to become round or practically round.

Pure Corectopia. (After Van Duyse.)

Corectopia. The normal pupil is not situated exactly in the center of the iris, and it is not unusual to find one or both pupils slightly eccentric, but a marked deviation constituting a clinical corectopia is rather a rare condition. Gescheidt gave the name corectopia to this abnormality. The normal pupil is situated slightly in and up, directly in, or down and in. The latter is the most frequent. A displaced pupil is often small, inactive and not always completely circular. The dividing line between a normally eccentric pupil and one to which we apply the designation corectopia, is of necessity not clean-cut. In well-defined cases the pupil lies so near the corneal margin that it is separated from it by but one or two millimetres of iris tissue. The classification and grouping of this anomaly has been done in an excellent manner by Best. He divided it into four groups. 1. The eccentric position of the pupil is the only anomaly. The other parts of the eye are normal, as is also the visual acuity. The direction of the ectopia

shows no constancy. The condition is not rare. The pupil as a rule is elongated and oval, or with a more or less triangular or irregular form: it is surrounded by sphincter and reacts normally. In the iris there are no evidences of a former intra-uterine inflammation recognizable. The condition is in the vast majority of the cases unilateral. 2. In this group, as Samelsohn early emphasized, the iris shows a dirty discoloration, and a decided change in its structure. The iris shows evidences of inflammation and is atrophied and irregularly pigmented. The pupil reacts badly or not at all. The iris border on the side of the deviation is atrophied in the pronounced cases, and the radial fibers, instead of converging towards the center of the pupil, converge towards the atrophied part, so that it resembles in appearance an iridectomy; in fact all variations in the shape of the pupil from a normal round one to an iris coloboma may exist. The occasional presence of a peripheral corneal scar arouses the suspicion of a possible perforation due to intra-uterine inflammation with a consequent iris prolapse and displacement of the pupil. Rindfleish observed such an occurrence, but did not designate it corectopia. Yet there was good ground for belief that the relation was close. The lens is clear and normally placed. Samelsohn observed a widening of the pupil with loss of reaction, and an increase in tension, but without excavation. This was no doubt a secondary condition. 3. As a complication of other congenital anomalies of the eye, for example buphthalmus, but it is impossible to say if a common factor is the cause in both. Other concomitant defects are albinism, epibulbar dermoid, coloboma of the lid, microphthalmus and dermofibroma. In coloboma of the iris, particularly in typical coloboma, the pupil is often displaced due to the pull of the sphincter fibers in the pillars. 4. The commonest type of corectopia is associated with ectopia lentis. Damianos has carefully tabulated these cases. Nearly always both eyes are affected. Unilateral cases are cited by Wilde, Steffan, Van Duyse; in the latter case the ectopia of the pupil was unilateral, whilst the ectopia of the lens was bilateral. Lens and pupil are both ectopic. Iridodonesis is present, especially in the area where the lens is absent due to lack of proper support. The position of the pupil is symmetrical in twelve per cent. of the cases. In the other cases it is more or less asymmetrical, and in a few cases the ectopia is in opposite directions in the two eyes. In the cases tabulated by Damianos the directions of the deviations showed the following percentages, up and out 35.2 per cent.; down and out 13.6 per cent.; up and in 13.6 per cent.; down and in 7.9 per cent.; down 11.3 per cent.; up 9.1 per cent.; out 5.7 per cent.; and in 3.4 per cent. The structure of the iris is usually normal but may show

changes; its reaction is normal. The lesser circle, radial and circular fibers show at times defective development. While the pupil reacts it is frequently sluggish. Where no reaction is present it can be attributed to other complications, as glaucoma, amaurosis or detached retina. The pupil is oftentimes very small, its shape is varied being round, oval, pear-shaped, slit-like, tri-angular or irregular. The size and form of the pupils of the two eyes may show slight deviations. The lens is generally clear, sometimes increased in size, sometimes diminished. Secondary cataract also occurs. The zonular fibers only exceptionally are missing. In recorded observations their presence is usually emphasized.

Lenticonus was observed by Lindner. Coloboma of the lens has been seen. Where ectopia lentis is present the lens is displaced in the opposite direction to the corectopia in 64 per cent. of the cases (Breitbarth). Coloboma of the inner coats of the eye has never been observed, but very often a temporal or circum-papillary depigmentation is seen. In 16.3 per cent. of the cases, remnants of the pupillary membrane were found. The refraction where the lens is not displaced out of the pupillary area, is generally myopic. The myopia may be axial; posterior staphyloma was present in 24 eyes out of 41 patients (Parsons). Hyperopia of varying amounts with different patients occurs if the lens is absent from the pupillary region. Monocular diplopia is present when the lens margins divides the pupil. The vision which is generally reduced is so because of optical reasons as the fundus is usually normal. Some cases have perfect visual acuity. The condition is not hereditary but quite often occurs in brothers and sisters whose parents are unaffected, and who show only errors of refraction, usually myopia. Consanguinity was noted by Pufahl and Best. Anatomical examinations of corectopia have been made by Von Ammon and von Hippel. In von Hippel's case the examination was thoroughly made of a high grade in and down displacement, with accompanying ectopia lentis up and out. The narrow nasal rim of iris was found three times the thickness of the stretched outer portion. There was no reason to think that the thick and thin parts represented an overdevelopment of the one and underdevelopment of the other. Von Hippel thought the condition resembled those mechanical ones found in adherent iris though there was no evidence of perforation at the limbus. Several explanations as to the cause of the anomaly have been formulated. The hypothesis of Samelsohn is that normally the lens invaginates the primary vesicle in a direction from above and out, to down and in, accounting thereby for the normal position of the pupil slightly down and in. He therefore explains corectopia as

due to an eccentric invagination of the vesicle. What this has to do with the development of the iris which occurs so late as the fourth month, is hard to understand, and von Hippel dismisses the hypothesis as mere speculation. Another conception is that a localized fœtal inflammation of the iris with contraction and consequent stretching of the opposing part, is the cause. This would agree with the anatomical findings of Von Hippel who thinks that localized fœtal iris inflammation is the most probable factor. To asymmetry of the optic cup Best attributed the cause of corectopia. Pressure of the amnion or of amniotic bands is assumed as the cause of corectopia by Van Duyse. Not only this but to such cause are also ascribed polycoria, atypical colobomata of the iris, ectopia lentis and lens opacities. The changes are thought to be brought about by mechanical pressure and interference with the blood supply. Just how and why such adhesions would come to occupy a symmetrical position in the two eyes and produce identical results is very difficult to comprehend.

Ectropion uveæ. Ectropion of the uvea is a condition normal to the horse where black nodules found at the pupillary edge consist of an accumulation of pigment epithelium on a connective tissue base. The same arrangement probably exists in the human congenital variety. Reis came to the conclusion that in ectropion of the uvea the appearance of the iris pigment layer on the anterior surface of the iris at the pupil edge may be a congenital condition as well as an acquired abnormality, the result of inflammatory changes in the iris. Okuse examined a section of iris removed from the eye of a youth with ectropion uveæ. The iris tissue was much pigmented especially the anterior layers. The sphincter, both in width and thickness, was of enormous size. It was bent sharply outward toward the pupillary margin so that the inner end of the muscle layer reached far forward. The posterior pigment layer was much thickened; at the iris root it was thicker than normal. The nearer the pupillary margin the more irregular the outgrowths became. At the pupillary margin there was a triangular cavity formed by the projecting outgrowth. Of the walls of this cavity the inner was thick, while the lateral ones were thin. The posterior wall was irregular. The surfaces towards the cavity were smooth. In front of the triangle was another pigment knob. The cells were cylindrical in type. He considered the condition as an anomaly of development consisting in a modified growth of the epidermal layer of the iris. Bock, as a result of finding only pigment epithelium, concluded that these masses were remnants of pupillary membrane, evidently an erroneous conclusion. The pigment masses are sometimes known as grape clusters. They are frequently enor-

mously developed, but as a rule do not interfere with the movements of the iris. At times a mass becomes free in the anterior chamber. Ectropion uveæ is often associated with other abnormalities and may be found with buphthalmus, aniridia and with coloboma iridis. Rarely minute cysts have formed from the free masses.

Congenital entropion uveæ has been described, but it is a question if it is really congenital. Enslin reported a case. The pigment epithelium was pulled backwards and outwards from the pupil.

Cataract. While under a number of cataract headings congenital types are treated, it will here not be amiss to briefly speak of the various forms.

The forms found at the anterior part of the lens are generally designated anterior polar cataract, but a more exact nomenclature would be that of anterior capsular cataract, and anterior polar cataract. There is no doubt that such cataracts may be congenital, as proven by the frequent simultaneous occurrence of other types of congenital cataract.

Congenital cataracts are divided as regards the extent of the opacity into partial and complete. In the former, as the name implies, but a portion of the lens is opaque. These constitute by far the largest number of cases of congenital cataract. Total or complete cataract, as a congenital anomaly, is rare. The partial cataracts are further divided as regards their situation into so-called (a) anterior polar cataracts, (b) posterior polar cataracts, (c) lamellar cataracts, (d) nuclear cataracts, (e) dotted cataracts.

Anterior polar cataract, (1) anterior capsular (2) anterior cortical. The name anterior polar is reserved for those cases where the opacity is situated at the anterior pole of the lens within the capsule, being a true opacity of the lens substance. The term anterior capsular cataract should be confined to those cases in which the opacity is external to the capsule and which as a rule is the result of a persistence of a part of the pupillary membrane. That an anterior capsular cataract may occur in the young without a perforation of the cornea was long ago pointed out. Intra-uterine inflammation has been held by some to be the cause of this condition whether perforation of the cornea had occurred or not. In extra-uterine life it is well known that the formation of anterior polar cataract is generally the result of perforation of a corneal ulcer which permits the anterior lens capsule and the posterior surface of the cornea to come in contact. This ulcer need not be central, may in fact be peripheral, and furthermore need not perforate at all. The process of formation is still a mystery. Some hold that the capsular epithelium is directly stimulated to proliferate,

others think that some destruction of the cubical cells is a necessary preliminary to the proliferation of the epithelium. Treacher Collins believes that a contact of the lens with the cornea causes an arrest of

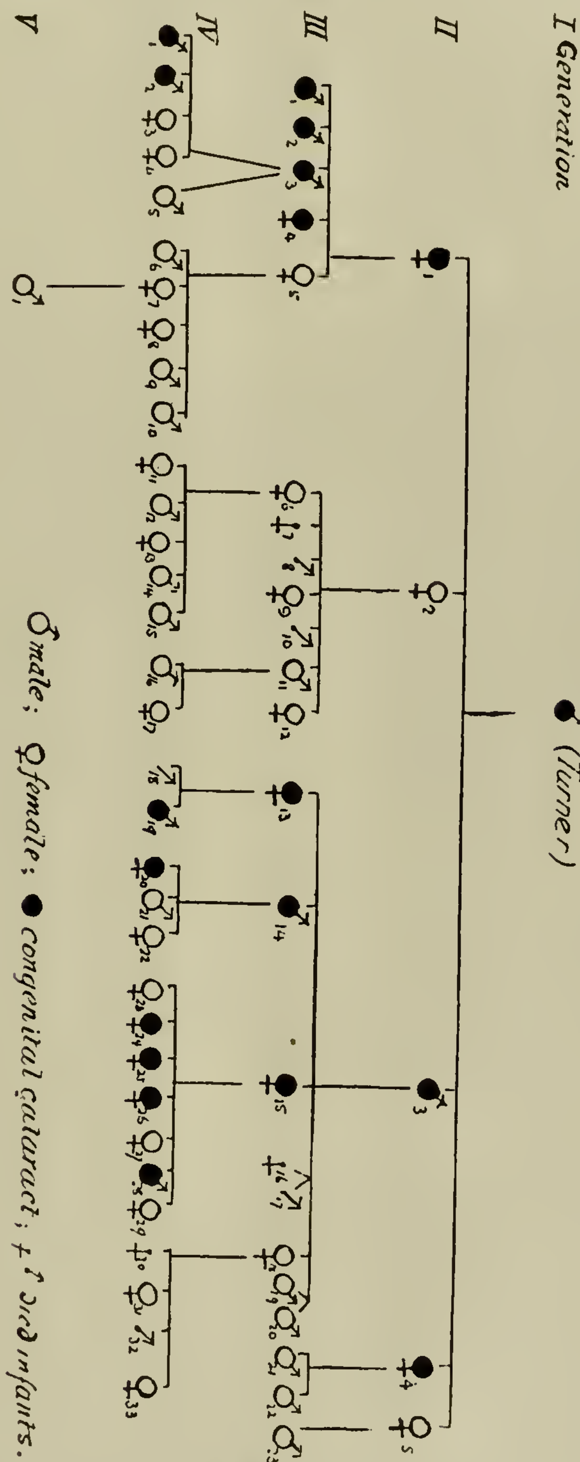
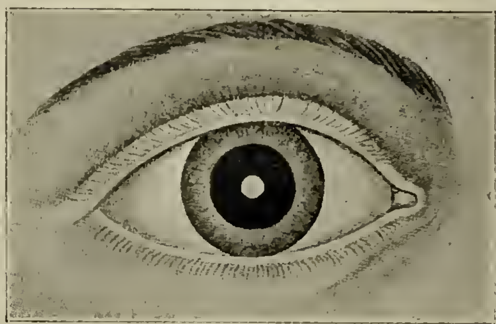


Chart of Congenital Cataract. (After Bishop Harman.) A pedigree of five generations.

osmosis of the nutrient fluid, this in turn producing a breaking down and shrinking of the lens fibers in the vicinity. As a result of this shrinkage the tension of the overlying capsule is released allowing direct proliferation of the epithelium without any preceding destruction. Whichever theory is correct the same explanations are applicable to the congenital variety, if we grant the possibility of an intra-uterine inflammation as the etiological factor. Hess thought it more likely that some impediment to the separation of the lens vesicle retards the closure of the anterior capsule. In support of this are the instances of bilateral anterior capsular cataracts without any evidence of inflammation. It is frequently difficult to exactly localize the position of the opacity clinically and to say positively whether it is anterior capsular



Anterior Polar Cataract. (After Nettleship.)

or anterior cortical, and it is possible that both may be present at the same time. Vallaro recorded fully the details of a well marked pyramidal cataract where there was nothing to indicate that there had ever been a corneal lesion. A large horn-shaped opacity, pure white in color, projected through the pupillary area into the anterior chamber from the anterior surface of the lens. The condition existed from birth. The cataract formation was composed of alternating layers of epithelial cells and fibrous tissue of a hyaline appearance which resembled in a way the posterior layers of the cornea, and from this it was inferred that pyramidal cataract is of a structure analogous to that of lens cortex and capsule, or Descemet's membrane and its epithelial lining. The various theories put forward to account for these cases of pyramidal cataract in which no lesion is or has been present were given as follows: 1. Abnormal persistence of the pupillary membrane (Beck, Vennemann), or perivasculitis of the pupillary membrane (Dor). 2. Incomplete closure of the lens vesicle and formation of an opaque substance in the position of the gap (Ammon). 3. Incomplete or irregular separation of the peduncle which unites the opening of the lens vesicle to the posterior surface of the cornea

(Hess, Rochon, Duvigeaud). 4. The action of a toxin, circulating in the anterior chamber and due to intra-uterine iritis or iridocyclitis which causes irritation of the lens epithelium in the anterior part opposite the pupillary area (Valude, Passera). Alt in 1899 from his microscopical studies of a number of eyes with anterior polar cataract formulated a theory for their explanation. He stated that the prime cause probably is a congenital malformation of the lens. This malformation represents a break or breaks in the continuity of the capsular epithelium layer as well as a dissolution of contact between this layer and the lens capsule. With such a pre-existing anomaly the

Congenital Stellate Anterior Polar Cortical Cataract.

(a) Right Eye with Complete Star; (b) Same in the Left Eye with the Star Incomplete. (After Wintersteiner.)

lens capsule would be in the same condition as Descemet's membrane after a loss of continuity in its endothelial lining; it would permit of the penetration of substances through it and into the lens in the manner suggested by Hulke or Nuel. This penetration, in turn, might be followed by the formation of an anterior polar and pyramidal cataract.

Posterior polar cataract. Here again the distinction should be made between posterior cortical and posterior capsular. The latter has been considered under hyaloid artery of which it is usually a persistent remnant, and make up no doubt a large proportion of cases described as posterior polar cataract. True congenital posterior cortical cataracts do occur and some are related to the lamellar type, evidenced by the occurrence of lamellar cataract either in the same or in the fellow eye. Those occurring with posterior lenticonus are not true cataracts. Some acquired posterior cortical cataracts are the result of malnutri-

tion and this has been urged as a possible explanation of some of the congenital cases, in that they may be the result of intra-uterine inflammation. In this connection may again be mentioned the experiments of Pagenstecher regarding the influence of naphthalin feeding, who shows that there exists a congenital toxic cataract. Experiments were carried out in rabbits, and cataract was produced in 100 per cent. of the offspring. To exclude the influence of the separation of the lens vesicle, feeding was commenced on the 21st day. The lens vesicle separates on the eleventh day and fœtal development lasts 33 days in

Congenital Perinuclear Cataract (a) with Stellate and (b) Anterior Cortical Stellate Opacities.

Focal light. (After Wintersteiner.)

the rabbit. The results were as follows: 1, a small central cataract; 2, an irregular posterior polar cataract; 3, a spindle-like formation with anterior capsular cataract; 4, a punctate capsular cataract with calcifications; 5, a discoid posterior cataract. Not only did Pagenstecher produce cataracts by this procedure but other maldevelopments were produced, viz., coloboma of iris and choroid, persistent hyaloid artery, posterior lenticonus, coloboma of the lids, microblephary, microcornea and adhesion of the conjunctiva to the cornea. These defects occurred in the offspring of animals themselves free from defects, and furthermore they produced normal offspring after napthalin feeding was stopped. The deformed rabbits produced normal offspring. Pagenstecher thinks his results minimize the theory of hereditary anomalies of the germ and throw light on the possibility of a toxic origin for congenital malformations. Hess thought that cen-

tral spindle, polar and lamellar cataracts were true deformities dating from the time at which the lens vesicle is separated. Von Hippel's experiments disproved the theory of a germinal defect, as he was able to produce cataract by the action of X-ray and cholin upon the fœtus.

Zonular, perinuclear or lamellar cataract is one in which the form of the opacity of the lens is that of a layer of opaque substance situated between a clear nucleus and clear cortex. Many cases have been examined microscopically, Deutschmann having been the first to do so. The opaque zone between the normal nucleus and cortex is made up of a granular substance, or as Deutschmann described it, the lens fibers were altered by the presence of numerous vacuoles and droplets of

Congenital Perinuclear Cataract. Focal illuminations. (After Wintersteiner.)

"myelin" and that a granular débris filled the tissues between the fibers. The nucleus may be shrunken and distorted and may be adherent in rare cases to the posterior or anterior capsule. In other rare cases a second partial or complete opaque layer is seen with clear lens substance between. Occasionally radiating spokes or riders resembling in appearance the handles of the steering wheel of a ship are seen or dense dots of opacity occur.

Lamellar cataract nearly always affects both eyes. It is as a rule stationary, though there are cases in which it gradually develops into a total opacity. Inheritance of lamellar cataract is rather frequent. The amount of interference with vision is variable, depending on the denseness of the opacity and hence it varies from almost normal sight to considerable diminution of vision. The exact manner in which these changes are brought about is still unknown. By some it is considered as a deposit of a pathological layer of lens fibers around a normal

nucleus (Horner), the exciting cause being rickets. Beselin and Schirmer take the view that a nutritional disturbance is at the bottom of it. Beselin thought such disturbance affected the whole nucleus which in early fœtal life constitutes the whole lens, the resulting con-

Punctate Congenital Cataracts Combined with Stellate and Perinuclear Opacities. Focal illumination. (After Wintersteiner.)

(a) Congenital Coerulean (Punctate) Cataract, and (b) Simple Punctate Cataract. By focal illumination. (After Wintersteiner.)

traction producing fissures between the nucleus and the subsequently-formed cortical layers. Schirmer took the view that malnutrition caused the production of vacuoles in the lens substance. The fibers

formed later being normal and transparent. Central cataract, lamellar cataract and total cataract are described as representing the effects of malnutrition, the result depending upon the time and intensity of the disturbance—central cataract by early and severe, lamellar cataract by later and less intense, and total cataract by a much prolonged disturbance. Three kinds of changes are noted microscopically. 1. Fissures between the lens fibers concentric to the nucleus, and which may or may not contain a granular substance. 2. Small round or oval vacuoles averaging .005 mm. in diameter, at times containing a hyaline substance. 3. Spaces averaging .02 mm. in diameter with irregular margins and generally circular and containing a granular substance.

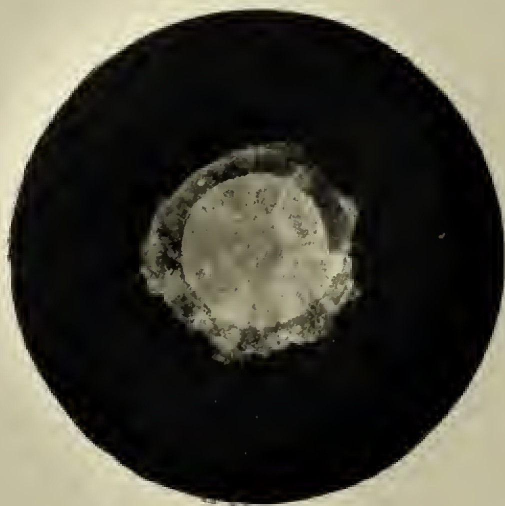
Congenital Punctate Cataract Combined with Anterior and Posterior Stellate Opacities. Focal illumination. (After Wintersteiner.)

These three changes are in keeping with the clinical appearance viz.: radiating spokes, the uniform haze and the denser dots. Literature dealing with the microscopical findings is to be found in the writings of Deutschmann, Beselin, Schirmer, Lawford, Hess, Treacher Collins, von Hippel, Alt, Beck and Heinzel.

It has been repeatedly noticed that the condition is a disease of childhood and that the children so affected suffered from rickets and convulsions. In fact lamellar cataract has been spoken of as an ocular manifestation of rickets (H. Knapp). The association of tetany has also been observed. The greatest number of cases are seen in early childhood though true congenital cases do occur but are said to be rare. Measurements of the ring of opacity, as compared with measurements of the fœtal lens, show that it is never larger than the lens at birth, but on the contrary is usually smaller, at times much smaller.

Infrequently it is of equal size of the lens at birth. From these observations the indications are that the lamellar cataracts occur before birth, but are not absolutely conclusive as such changes are known positively to have occurred after birth. However, the discussion still wages as to whether lamellar cataract is congenital or infantile.

Central or nuclear cataracts are closely related to the lamellar type. Eyes affected with this kind of cataract frequently show other congenital malformations also, or are found in patients whose mental and physical development is below par. In families with congenital cataract the central variety may be found in one generation and lamellar



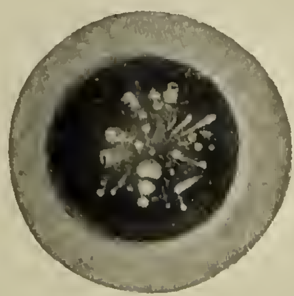
Lamellar Cataract. (After Parsons.)

The lens was extracted and photographed in water. The clear peripheral cortex is seen adhering to the cataractous part.

in another. These opacities are generally sharply circumscribed, regular in shape and usually found in both eyes. Cases of unilateral cataract, however, have been described by Schirmer and Oncken. The nucleus is often situated far back in the lens (Hess).

Coppock, discoid or Nettleship's cataract. A peculiar hereditary congenital cataract similar to that described by Nettleship and Ogilvie is recorded by Burton Chance. It affected five members of a family. These cataracts were partial and circumscribed, of the same kind in every case, and large enough to block the pupillary spaces. They were bilateral, and exactly symmetrical in the two eyes, and appeared to be stationary. The exact position was difficult to define. They were neither polar nor nuclear, but seemed to be between the posterior pole and the nucleus. The discs were extremely thin. The visual acuity was below normal in every case, myopia being present and varying from one to five diopters.

Another very similar case is reported by Crampton. The vision in each eye was 6/20. There existed a markedly similar film-like cataract in each eye, best seen with transmitted light and remarkably circular



Coralliform Cataract. (Marcus Gunn, *T. O. S. U. K.*, XV.)

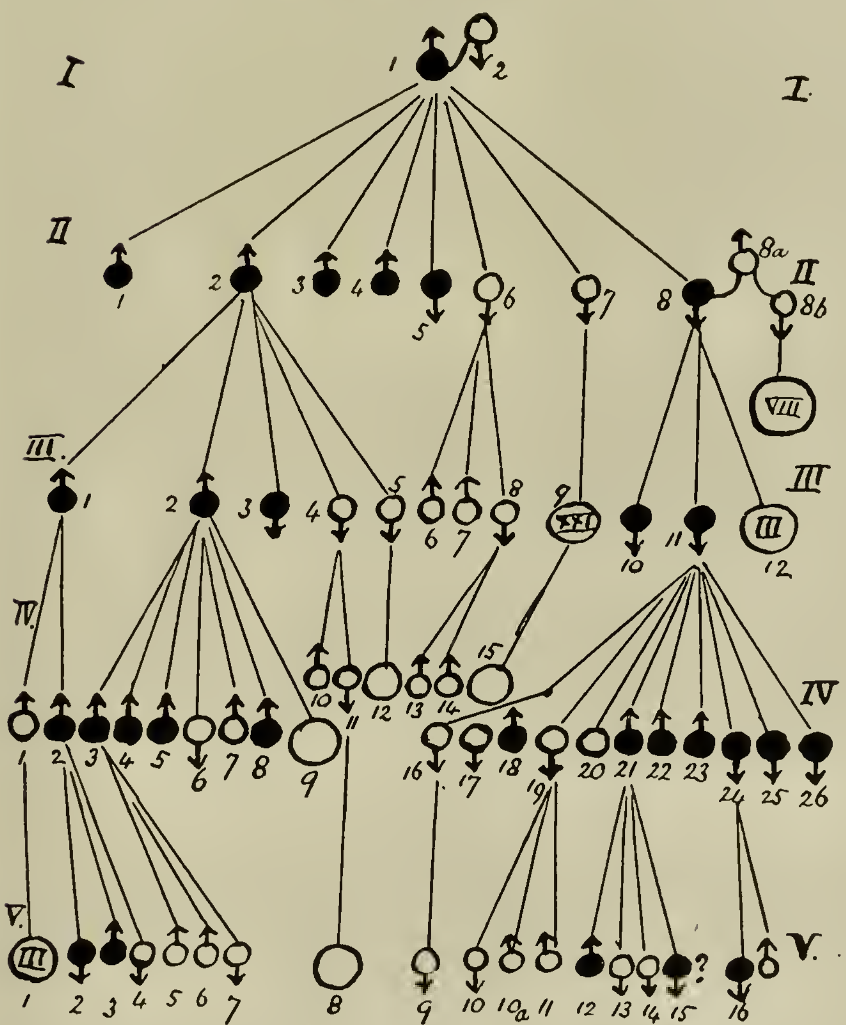


Chart Showing Heredity in Coralliform Cataract. (After Nettleship.)

in outline, measuring 5 or 6 mm. in diameter. It was probably situated between the nucleus and the posterior pole. The index of refraction

appeared to be different from the remainder of the lens. Occupying the center of each was a dotted triangle with base up. This case and Chance's are examples of what is now designated Coppock, discoid or Nettleship's cataract. A central cataract which may be regarded as the ultimate expression of a lamellar cataract with very extensive nuclear changes is seen in some cases with dense central and punctate peripheral opacities (Parsons). Hess showed that these are flattened lenses spindle-shaped in section with a very thin layer of clear cortical fibers.

Fusiform, spindle, axial or coralliform cataract is a rare variety given the various preceding names on account of its shape or position. It is characterized by an opaque stripe extending from the anterior to the posterior pole. In the coralliform type there is an opaque core of variable diameter from which radiate in all directions, and often throughout its entire course, opaque spokes ending in trumpet-shaped enlargements. The appearance may exactly simulate coral. It is at times combined with zonular or with central cataract. The hereditary influence is quite marked and it occurs as a family disease, attention to which was drawn by Nettleship. Heredity, however, is not always a factor, as in a case of Kipp's.

Congenital fusiform cataract was first definitely described by Becker. Von Ammon, Pilz, Müller and Becker described coralliform cataract and drew attention to its association with the central and lamellar varieties. Knies sought to explain the origin of the spindle or fusiform shape as resulting from an adhesion of the nucleus to the anterior and posterior capsules, the further development of the cortex drawing the nucleus out into a spindle form.

Dotted cataracts are observed as numerous small widely-scattered opacities of the lens. They are found in all parts but commonly in the periphery. With a dilated pupil and not too strong illumination they are sometimes seen as irregularly-shaped opacities having a bluish reflex. The condition is usually hereditary. The discovery is made accidentally during a routine examination, as the opacities produce no subjective symptoms, visual acuity being good.

Total cataract, as its name implies, is a general opacity of all of the lens fibers, the color being a uniform grayish white. In discussing lamellar cataract total cataract was spoken of as the result of an early and more prolonged malnutrition, whereby all fibers were affected. A lamellar cataract may develop later on into a total cataract.

According to their consistency total cataracts are divided into three classes. 1. Fluid cataracts, the contents being thin and constituting with the capsule a bag filled with liquid degenerate lens substance.

On opening the capsule the contents run out and the capsule is at once completely emptied. 2. Here the consistency is much greater; the lens substance is of a milky-white, even color. The consistency is that of a normal juvenile lens. 3. In these cases the opacity is densely white. The lens is flattened and shrunken. Some of the shrunken lenses have a white, chalky mass in the pupillary region with a deep anterior chamber and iridodonesis. These latter cases are supposedly due to an intra-uterine inflammation which may have a syphilitic basis. Another explanation for shrunken total cataracts is that the opacity and failure in development of the lens are results secondary to a persistence of the hyaloid artery. A total cataract reported by Gilbert, of Munich, was due, in that author's opinion, to a rupture of the posterior capsule from shrinking of a persistent mesodermic appendage. In his case the examined eye was slightly microphthalmic, but its fellow was of normal size and also had total cataract. Total cataract is a relatively rare condition, being found less frequently than lamellar cataract.

Cataract in microphthalmus. This is a very common occurrence and varies in its completeness from the very slightest grades to complete cataract. It is frequently associated with ectopia lentis. The cell remnants may be calcified. A case of familial cataract was reported by Casey Wood in which Alt found lime crystals in the nucleus.

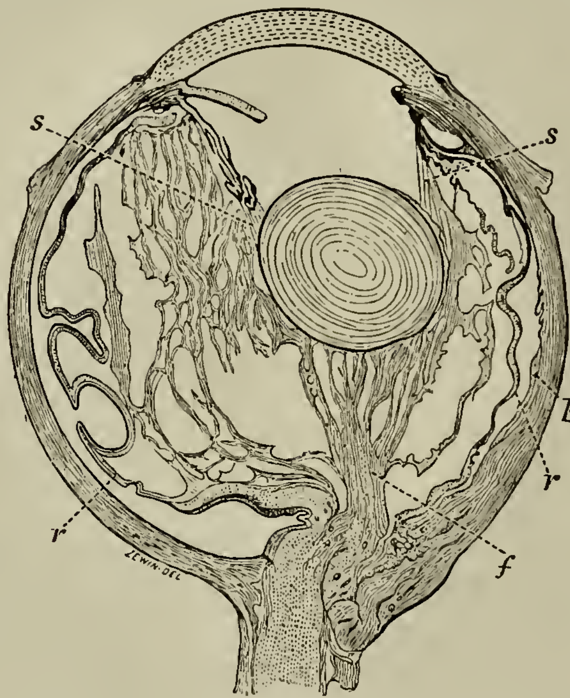
Ectopia lentis. Congenital displacement of the lens (ectopia lentis) is a comparatively rare anomaly. Knapp saw ten cases in fifty thousand patients, making a ratio of one to five thousand. Zani, in 1909, stated that not more than one hundred and thirty-five or one hundred and forty cases had been observed. This would appear to be somewhat under the mark. No doubt quite a number have been observed but unrecorded. Extreme care should be exercised, however, in reporting a case as congenital for, as is well known, luxation subsequent to birth frequently occurs due to defective or missing zonular fibres and confusion with congenital luxation may readily occur. The condition is usually bilateral and is found also as a family and hereditary trouble. Martin recorded its occurrence in five successive generations comprising ten individuals. Before and since then numerous observers have noted the pronounced hereditary tendency (Graefe, Dickson, Williams, Sattler and others). The direction in which dislocation occurs varies and is usually symmetrical in the two eyes. In the great majority it is upwards, inclined slightly outwards or inwards, usually the former. Other positions assumed are down and in, outwards, down and out, the frequency being in the order named. As exceptions to the general rule, one lens may be dislocated in one direction and its fellow in another (asymmetrical), for instance, in two recorded cases the

Congenital Displacement of the Lens. (After Morton.)

right lens was down and out, the left down and in, in another case the right down and in, the left up and in (Dorsch). Jackson reported the

case of a boy with the left lens dislocated inwards, the right inwards and downward. It is said displacement never occurs directly downwards, though in one of Adams' cases the lens is described as completely dislocated downwards. Displacement backwards sometimes occurs in microphthalmic eyes as a result of some defect in the development of the vitreous. In three children of a total of six affected individuals reported by A. R. Gunn and with otherwise normal eyes, the lens in each instance could be seen floating free in the vitreous. Monocular diplopia is not often complained of for the reason that the pupils are usually quite small and the iris consequently hides the periphery of the lens. Knapp, however, met with an instance in which four images were perceived simultaneously with the two eyes. As seen clinically, the edge of the lens may or may not occupy the pupillary region, dilation being necessary to see the edge and our attention being drawn to the eye primarily because of the iridodonesis. Where the pupil is large enough to reveal the lens edge, it is divided consequently into a phakic and an aphakic part in which cases monocular diplopia must supervene. The anterior chamber is deepest on the aphakic side, the side from which the lens is displaced. The iris is found tremulous (iridodonesis). The edge of the lens by reflected light appears as a dark crescent, the lens itself being gray and the aphakic part at its margin black. The dark crescent is due to the strong prismatic refraction. The curved edge of the lens, as seen with the ophthalmoscope, is not always regular but may show slight depressions or elevations. The depression in the border may amount to a notch, constituting a coloboma (Marcus Gunn). Occasionally the margin instead of being convex is nearly a straight line. The suspensory ligament as a rule is completely absent in the region corresponding to the aphakic area, the lens being dislocated away from the point of the absent zonule. Absence of the suspensory ligament produces a movable lens. Relative to this the case reported by Bowman is of interest. The lens apparently swayed forward, interfered with the passage of fluids through the pupil and thus caused a rise of tension. In one of A. R. Gunn's cases the lens temporarily migrated into the anterior chamber in one eye and set up such an irritation, iritis, etc., that it was necessary to extract it. Frequently the lenses are smaller than normal, being more round in shape and resembling the fœtal lens. Lindner reported four cases where the lens was larger than normal in all diameters. Iritis and cyclitis or adhesions resulting from previous uveal inflammation have been at times observed, excited no doubt by the mobility of the lens. The tendency to dislocation into the anterior chamber, prevented in most cases by the small size of the pupils, is

explained by Hess as due to the softness of the juvenile lens. Associated with ectopia lentis, there are frequently found other defects, chief among which is coloboma of the iris, generally in the opposite direction, other defects being corectopia, aniridia and nystagmus. Stroud reports congenital disloeation of both lenses with corectopia in six members of a family of seven. No other malformations were present. All members of the family had brown irides which reacted to light, and marked iridodonesis. The lens is usually clear. A number of opaque lenses have been reported and are affected in one or both



Semi-Diagrammatic Sketch of a Microphthalmic Eye. (*Trans. Ophth. Soc. U. K.*, Vol. XIII.)

f, Fibrous tissue in centre of vitreous holding lens back; *s*, suspensory ligament of lens stretched and attached to elongated ciliary processes; *r*, retina much folded; *p*, position at which the choroid in the lower part of the eye commenced, and where the pigmented epithelial layer first became pigmented.

eyes in about an even number. Ectopia lentis, and in like manner coloboma of the lens, is the result of some defeet in the development of the suspensory ligament, which is more pronounced in the former than in the latter. What occasions this defeet is susceptible of several explanations. 1. That the suspensory ligament may be ruptured after its formation. This is supported by the faet that the lens has reached complete development; but nothing is brought forward to explain how and why the rupture takes place. 2. That it is prevented from forming at all. The lenses are usually displaced upwards and this is explained in this manner. Failure or late closure of the fœtal cleft oecurs in the

ciliary region so that as the eye grows there is no suspensory ligament to retain the lens in that region and hence it is drawn in the opposite direction. This, of course, explains the typical dislocation. For the atypical cases another explanation is necessary. In early development of the lens it virtually fills the secondary vesicle which later by its rapid growth draws away from the lens. During the stage of contact of the lens equator with the ciliary region, adhesions are formed which when these two structures separate are drawn out into fibres which ultimately become the fibres of the suspensory ligament. This is Treacher Collins' conception of the suspensory ligament formation. Now anything which would interfere with this preliminary contact, whether at the fœtal cleft, as is most usual, or at any portion of the

Ectopia Lentis, Pupil Undilated. (Marcus Gunn, *T. O. S. U. K.*, IX.)

periphery of the lens, would produce this defect. This could be due to a partial persistence of that portion of the intruding mesoblast which passes forward in all directions around the lens equator to join with the mesoblast growing in anteriorly to form the capsulo-pupillary membrane. Wherever a strand of this tissue persisted, development of the suspensory ligament would fail. The complete development of the iris in the majority of cases does not apparently support this theory, but the late development of the iris and the supposition of only a temporary persistence of a mesoblastic strand may permit this theory to be applied to some cases, especially those of atypical ectopia lentis. Zani, reviewing the theories, inclines to that of Badal as completed by Lagrange. According to this, all eyes with such an anomaly are myopic and on account of the form of the eyeball the lens is small in size as compared with the space it should occupy. The over-stretched zonula yields and the lens is displaced towards the side in which there is the least resistance. An interesting point, and one to which attention has been drawn and which has received further corroboration by Zani, is that the patients observed are always intelli-

gent and well-developed children. Adams, however, on the contrary states that of a mother and nine children observed by him, of whom seven children have displacement of the lenses, the two unaffected appear to be more intelligent and "obviously different" from the others. As has been previously remarked, the hereditary factor is very marked. Lewis found sixteen cases in six generations of one family. In A. R. Gunn's series the pedigree was examined into closely and discussed as follows: "Examination of the pedigree shows at once that the condition is certainly not a Mendelian recessive; also, that it affects both sexes in equal numbers. In two families with four and two children, respectively, it seems to behave as a pure dominant; in all the others there are both affected and unaffected individuals, the former predominating. The only unaffected individual who has a family, it is interesting to note, has all his children (four) unaffected.

Ectopia Lentis, Pupil Dilated. (Marcus Gunn, *T. O. S. U. K.*, IX.)

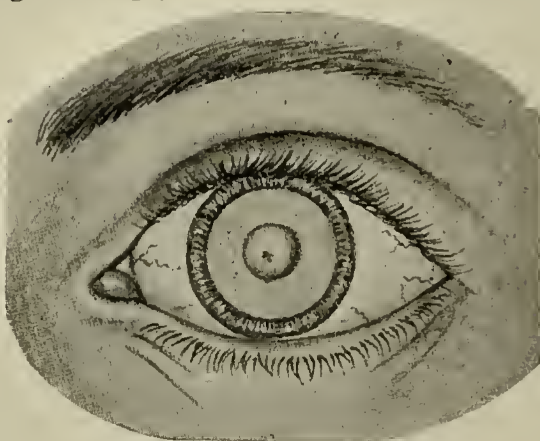
We may assume then that the normal condition is recessive to the abnormal and that therefore the latter probably differs from the others, not in lacking something essential to complete development, but rather in possessing some additional character or factor in virtue of which the normal development of the suspensory ligament is interfered with. On this assumption, and owing to the fact that the majority of families contain both affected and unaffected individuals, we must regard the affected individuals as heterozygous for this inhibitory factor. Assuming further that each marriage has been between such a heterozygote and a homozygous normal, which we are justified in doing in the absence of any history of cousin or other interrelation marriages, we should expect as the result an equal number of affected and unaffected offspring. The actual results, however, show a large preponderance of affected individuals. Tabulating the offspring of the union of an affected with a non-affected parent we find as follows:

Affected:	Non-affected:
4	1
4	1
4	0
3	3
2	0
17	5

The total of five such families is twenty-two, viz., seventeen affected and five non-affected individuals, a result suspiciously like the 3:1 simple Mendelian ratio. Further, on examination of the individual families, it is curious to find two containing: (1) members which apparently throw off only affected individuals when married to a normal recessive; (2) members which throw off both recessives and dominants, in one instance, in equal members; (3) one member at least breeding true to the recessive character. Such a result, however, is not in this instance found in association with the union of two heterozygotes, and at present we must regard its significance as unknown. We are justified, however, in tentatively concluding that (1) normal is recessive to abnormal and (2) the individuals exhibiting the latter condition are heterozygous in composition for a certain factor, in presence of which the usual development of the suspensory ligament of the lens is inhibited.''

Lenticonus. This is the term applied to an abnormal curvature or spheroidal condition of the anterior or posterior surface of the lens. Parsons states that up to 1906 but two cases of anterior lenticonus had been described (Webster, Van der Laan). Mohr in 1910 reported the occurrence of an anterior lenticonus in conjunction with absence of the canal of Schlemm, glaucomatous excavation and opacities of the cornea. The conicity of the lens surface is a condition analogous to keratoconus. In the two cases of lenticonus described by Webster and Van der Laan the condition was bilateral. Doubt exists as to whether these cases of anterior lenticonus were really congenital. Andrè Patry (1906) published a monograph on the subject of lenticonus, and he states that there were sixteen published cases of posterior lenticonus up to that date in which an anatomical examination had been made, two in man and fourteen in rabbits and pigs. In five of the cases the condition was bilateral. F. Meyer in 1888, first described the clinical aspects. Later attention was also called to the condition by Knapp, Eiseck, Mitvalsky, Cramer, Gullstrand, Elschnig and others. The condition is at times associated with opacities in the lens at the

posterior pole or elsewhere. In Mitvalsky's case there was a persistent hyaloid artery, and in Meyer's case a remnant of the hyaloid artery was adherent to the posterior lens surface. The presence of these hyaloid remains is supposed to indicate that such may, in a measure, be an etiologic factor in the production of posterior lenticonus. They at least draw attention to the congenital origin of the defect. In some of the cases the lens is perfectly clear. Lens opacities are present in approximately 80 per cent. of the cases. Persistent hyaloid artery is present in 60 per cent. of animals eyes examined microscopically. Posterior lenticonus is diagnosed ophthalmoscopically by observing a sharply-defined disc in the center of the illumin-



Posterior Lenticonus. (After de Schweinitz.)

ated area which gives the appearance of an oil drop in the lens. There is of course a difference in the refraction of the center of the lens and the periphery. The refraction is myopic, in the center highly so. In L. Müller's case there was a central myopia of 13 D. and a peripheral one of 4 D. In the cases with clear lenses Müller does not think there is a true conicity of the lens, but that there is some undue thickness or thinness of the nucleus and prefers to describe these cases as lenses with a double focus. False lenticonus, a condition frequently found in old age, is due to an increasing difference in the refractive index of the nucleus as compared with the cortex. The views given by Patry as to the cause of posterior lenticonus are classed under two headings. 1. The rupture of the posterior capsule due to an increased size of the lens. 2. The rupture and deformity of the lens are both due to traction produced by the hyaloid artery. Where there is a gap in the lens capsule the lens substance is either in direct contact with the vitreous or separated from it by a connective tissue membrane of variable thickness continuous with the canal of Cloquet. In some of Patry's cases the only changes in the lens itself were in the backward projection of the fibers into the vitreous, whilst in others more

extensive changes were present. Pergens' suggestion of a new growth of lens substance or phakome has not been accepted. Rupture of the posterior capsule due to increase of the size of the lens is difficult to understand: firstly, because some of the cases are without cataractous changes and hence no valid reason is seen for the supposed increase in size. Furthermore where cataract changes are present they are confined to the part of the posterior pole protruding into the vitreous; and secondly, why the capsule at the posterior pole should be the part to give way is not apparent (Collins). The second theory is not always applicable for the reason that in a large proportion of the cases no trace of a hyaloid artery was present. Collins further states that the opacities of the lens seen in connection with posterior lenticonus are different from those met with in traumatic cataract and are not always entirely localized at the posterior pole. Collins suggests that as neither of the two theories adequately explains the etiology of the posterior lenticonus, a more satisfactory one should be sought and thinks it is to be found in regarding the gap in the posterior capsule as a defect in development rather than a rupture and points to the fact that development of the capsule at the posterior pole has to be completed very early and that should it fail to form there is no way in later life by which the defect can be made good. This and the fact that Hess found the condition in a chicken embryo 150 hours old, gives support, he concludes, to the developmental theory. Subsequent growth of the lens would cause the gap to enlarge and the resulting protrusion of the lens fibers into the vitreous at the posterior pole would come about. Backward displacement of the nucleus is generally present. Mayou reported a case of microphthalmus resembling glioma with choroidal coloboma, posterior lenticonus and hypertrophy of the ciliary body. This case was of interest because of the complete absence of hyaloid remains, and a like absence of any gap in the posterior part of the lens capsule, but Collins found it thinner than normal. There was some distortion of the posterior lens fibers but no backward displacement of the nucleus.

Umbilication of the Lens. Otto Becker described this condition and Pechin proposed the name. It is a very rare congenital anomaly, the opposite of lenticonus (q. v.).

Colobomata. The term colobomata denotes a characteristic congenital defect. Applied to the eye it means an absence in part of a normal structure in a definite portion of the ocular structure. Most colobomata are situated in the region of the fœtal cleft and consequently occupy a position downwards, or downwards and slightly inwards. Because of this characteristic situation, they are termed

typical colobomata. The occurrence of the defect in any situation, other than the usual one is therefore designated atypical. The impossibility of the fœtal cleft being associated with the latter has aroused much speculation as to how they are brought about. This will be considered under the etiology of colobomata. The fœtal cleft is an early formation occurring during the first month at about the same time as the formation of the secondary optical vesicle, and the invagination of the lens. It serves for the entrance of the mesoblastic tissue, carrying the retinal vessels to the optic nerve and interior of the globe. It exists but for a brief time, but its remains are discernible for some time. It is obliterated by the union of homologous structures, retina to retina, etc., so that in the developed normal eye no trace of it is seen. The supposition that the fœtal cleft underwent a rotation subsequent to its formation in the characteristic situation, thus explaining macular colobomata, has been long abandoned along with the idea that the fovea was developed in the fœtal cleft. The finding of an accessory fœtal cleft, as was done in animals by Von Ammon and Van Duyse, has not been confirmed in the human embryo and can hardly be expected to explain the occurrence of atypical defects in man. Sex probably has no influence on the production of colobomata. The female has been supposed to suffer most frequently, but this is doubtful. Heredity occasionally seems to play a rôle, but its influence is not strikingly prominent, though quite a number of cases have been reported occurring in families. Aniridia, which may be considered as a total coloboma of the iris, shows the strongest hereditary tendency. The tables of Streatfeild, De Beck and Snell are given, showing the occurrence of coloboma of the iris in several generations.

Coloboma of the iris. This striking anomaly, because of its being so very apparent, came early to the notice of ophthalmologists and descriptions of it were furnished by early writers, among them Bartholimis (1673) and Albinies (1764) ; more complete observations were made in the early years of the last century and the name of Gescheidt is intimately connected with the defect. Coloboma of the iris may be met with as the only anomaly, or, as is frequently the case, other defects are present. Situated in the main downward, or downward and slightly inwards, it is called typical and is by far the commonest condition found. It consists of an absence of iris tissue ranging in the slightest forms from a mere nick in the pupillary border to a deficiency comprising 1/6 to 1/3 of the total area and reaching as far as the ciliary border. Incomplete forms are found in which the pigment layer alone is missing in a section corresponding to the site of the ordinary coloboma. This when viewed superficially, is taken for a

coloboma of the usual type, but upon closer inspection with oblique illumination its true character is recognized. Jackson reported a case where the left eye showed a slit extending downwards from the pupil less than ½ mm. wide, and looking like a streak of pigment or a large iris cleft. The ophthalmoscope proved it to be a true coloboma. It was separated from the normal pupil by a bridge of tissue ½ mm. wide. The movements of the iris and of the pupil were normal. By transillumination a coloboma 3 mm. wide was demonstrated and extended from the pupil to the ciliary region. Lens and choroid were normal. The coloboma involved chiefly the pigment layer. These are termed pseudo-colobomata.

Typical Coloboma of the Iris. (After Seggel.)

Absence in a similar manner of the iris stroma in a like situation also occurs. The commonest form of the defect is a gothic arch with the borders slightly converging to the apex at the ciliary border where the opening is narrowest. The apex is usually rounded off and, in incomplete forms, does not reach the ciliary border. The borders of the defect may be parallel or even diverge slightly, which with a pupil of ordinary size gives a form to the coloboma often spoken of as key-hole coloboma. Where the divergence of the borders is very marked a large portion of the iris may be missing constituting a partial aniridia, if the use of such a term is permissible. The iris pigment layer reaches to the edges of the coloboma, or slightly beyond them. The angle of the coloboma is frequently filled with pigment, in fact the whole gap may be thus taken up with pigment. The situation of the pupil is at times altered being more often displaced downwards and slightly inwards, than upwards.

The reaction of the iris to light or to the effect of drugs is very variable and depends to a great extent upon the size of the defect and the condition of the sphincter. Where the defect is partial the sphincter surrounds it and its behavior to stimuli approaches the normal. In

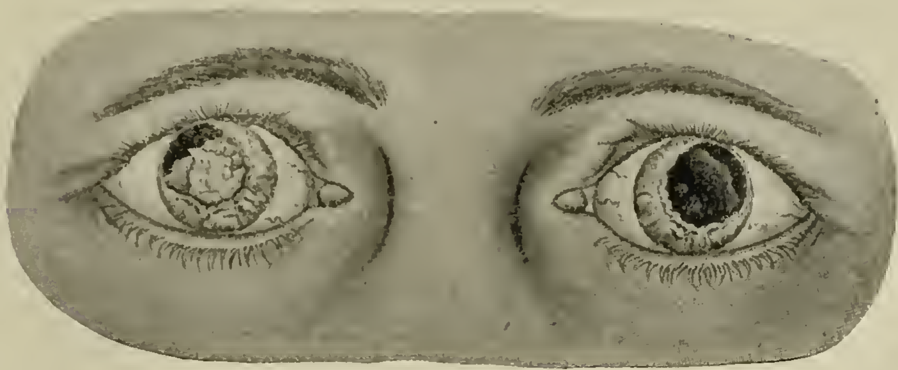
the large defects reaching to the ciliary border the sphincter is frayed out and is continued along the edges as a very thin, weak bundle of muscle fibers. A rare finding is the persistence of a strand of tissue between the pillars of the coloboma. Oftentimes it is but a bridge of pigment, again it consists of strands of fibers projecting from the lesser circle and made up of persistent pupillary membrane, and much less frequently the tissue is continuous with the iris tissue being attached to the edge of the coloboma. These instances constitute so-called bridge coloboma. The formation of a bridge coloboma from persistent strands of pupillary membrane or from pigment is not difficult to

Bridge Coloboma of the Iris. (After Saemisch.)

understand, but those bridges composed of tissue resembling iris tissue are difficult to explain on any hypothesis. In the iris of the colobomatous eye there is frequently an absence of the finer marking and also cysts. The shape of the cornea is often changed being somewhat narrowed and contracted in the lower portion.

In partial colobomata there extends downwards a pigmented line or streak which represents the continuation of the defect. This streak is situated on the posterior surface of the iris and is in that manner distinguished from a melanoma. Typical coloboma is probably the commonest anomaly of the eye met with. As a rule it is unilateral. Bock states that it is found more often on the left side, in the proportion of three to two, though later writers have failed to find a preponderance in favor of either side. A common accompanying defect is coloboma of the choroid. In other cases we find the iris coloboma but a part of a widespread defect, the ciliary body, choroid, retina and nerve being involved. These latter cases are relatively rare. Other defects than that of the choroid and ciliary body just mentioned are strabismus, nystagmus, hare-lip, coloboma of the lid, microphthalmus, changes in the size, form and curvature of the cornea, and lastly defects in other parts of the head and body.

An atypical coloboma is one occupying any position other than the usual one. The application of the term pseudo-coloboma to this condition is certainly wrong as the lesion is the same as in typical coloboma, differing only in direction. An atypical coloboma may be found in any direction, but out, in, up and out, up and in, down and out represents, in the order stated, the frequency with which they are found. Cases of coloboma outwards are reported by Mittelstadt, Bayer, Ruehlmann, Leber, Van Duyse. Inwards by Heyl, Mittelstadt, Macrocki, Czapodi, Steinhein, Rindfleisch, Seggel, Bock and McGillivray. Up and out by Hutchinson, Theobald, Page, Bock, Pfannmueller, McGillivray, Leber and Faber. Up and in, V. Reuss, Schiess-Gemuscus,



Bilateral Coloboma of Iris, Upward and Outward. (After de Schweinitz.)

Fage, Pollock, Hess, Leber, Gilbert and Yamaguchi. Upwards, Theobald, Rumschewitsch, Simonsin, Bock, McGillivray, Purtscher, Coover.

Atypical colobomata may involve a large part of the iris, sometimes a quarter or even a half. This may be the case especially where the other eye shows an aniridia. Zimmermann reported an atypical coloboma where the entire lower half of the iris was wanting. There were no other defects. An extremely rare occurrence is that of two colobomata in one eye. Such cases have been observed more frequently in animals and are termed multiple colobomata. Bock described a triangular pupil constituting a triple partial coloboma in a pig. Multiple colobomata have been confused with polycoria and certain varieties of persistent pupillary membrane. The shape of the atypical is similar to that of the typical coloboma, being pear-shaped or more like a gothic arch in most cases. Bridge coloboma is also met with. The arrangement of the sphincter muscle is also the same as in typical cases. Concomitant colobomata in other parts of the eye while not frequent are nevertheless observed. Thus we may find a typical

choroido-retinal coloboma with an atypical iris coloboma, or the reverse, a typical iris coloboma and an atypical choroidal one.

Histological examination of colobomatous irides show occasionally an absence of crypts. The pillars are thickest near the ciliary border and of normal or nearly normal thickness at the pupillary border. The pigment often projects beyond the borders as observed clinically. The sphincter at times is found absent but is usually frayed out and lost near the angle of the coloboma. The bridges of tissue are made up of connective tissue, those arising from the lesser circle being persistent parts of the pupillary membrane.

Coloboma of the lens. Coloboma of the lens is a rare anomaly. It consists of a defect in the margin of the lens nearly always at its lower border. It is possible that slight forms are frequently overlooked.

Coloboma of the Lens. (Marcus Gunn, *T. O. S. U. K.*, XXIV.)

Showing coloboma upwards, with defective development of the suspensory ligament.

The defect may occur in one eye or in both and is often associated with other anomalies, such as coloboma of the iris, ciliary body or choroid and ectopia lentis. Besides being displaced the lens may be partially opaque and smaller than normal. In 1899 Kämpffer collected and analyzed one hundred and thirty-two cases. He looked upon lens coloboma as a congenital defect in the edge of the lens with or without a true loss of substance, the remainder of the lens being normal in shape. The defect usually assumes a triangular or saddle-shape and extends through the whole thickness of the lens and varies in size from a small notch or indentation to a defect involving as much as a fourth of the lens substance. Cases have been divided into three classes: 1. Simple indentation. 2. A straight line which may or may not be broken by irregularities (crenated). 3. Projection to a point which may have an indentation at its tip (Bock). A remarkable case was reported by Doyne belonging to this latter class, in which there was a coloboma of the iris and choroid and the corresponding edge of the

lens instead of being notched showed a projeetion. The indentations may be single or multiple but two deep indentations close to each other are very infrequent. The anomaly is generally unilateral and is equally divided between the two sexes. The refraction is frequently found to be myopic (twenty-four times in eighty-two eases, Kämpffer); the reason for this being in great measure due to increased curvature of the lens, the result of relaxation of the zonule (Kämpffer). In some unilateral cases the affected eye has been found myopic while the normal fellow eye was emmetropic. Bowman and Heyl reported eases where the refraetion was hypermetropic. As stated, Collins is of the opinion that the zonule is developed by adhesions forming between the sides of the lens and the ciliary body at that period of fœtal life when they are in contact. Subsequent growth of the globe away from the lens eauses a stretching of the eells forming these adhesions into fibres whieh make up the future zonule. In case some of these adhesions fail to form there will be a corresponding laek of zonular fibres at that point. The lack of normal tension in the lens eapsule at the point corresponding to the missing zonular fibres would result in the failure of the lens to expand here like the remainder; consequently there would be a depression in the lens at that situation. This explanation of the formation of lens eoloboma depends entirely on the eorrectness of Collins' eonception of the development of the zonule. The evidence as to the condition of the zonular fibres is somewhat eonfusing. First of all it is difficult to see normal fibres of the zonule. Complete absence and eomplete development have been reported. Sehiess-Gemuseus and Cissel found the zonular fibres present even with large inferior colobomata. Beeker and Gunn also observed their presence. Bock found fibres present in two cases and missing in four others. Marple and Coburn's ease showed a defect at the lower margin of the lens; the lens was drawn upwards and the fibres of the zonule could be plainly seen stretching aeross the pupillary area. The typical situation of the defeet is downwards but may vary slightly from the vertieal in or out. Atypieal types are occasionally noted. Of the reported cases are, up: Knapp, Schaumberg, Rogman; in: Bass, Vossius, Kämpffer, and Hess; up and in, with corresponding eoloboma of the iris and choroid (Hess); up and out: Narkiewiez-Jodko, Schaumberg, with bilateral upward eorectopia; out: Schiess-Gemuseus, Kämpffer, Lang and Collins with corresponding coloboma of the iris; down and out: Christen, Cissel; and down and in: Cissel in the other eye. Toldt eollected seventy cases of lens colobomata, two of whieh were on the temporal side, five on the nasal, twelve upwards and fifty-one downwards. A question sometimes arises as to whether we are dealing with a colo-

boma of the lens or a dislocated lens. This doubt is apt to come up where the defect is represented by a straight line and not a notch. Isakowitz has described a case in which nearly one-half of the circumference of the lens was represented by three nearly straight lines. With the exception of a few strands the suspensory ligament was absent along these lines. In spite of this there was no undue mobility of the lens and the latter was properly centered. The lens was not large enough to receive all the rays entering the pupil, yet in contradistinction to patients with dislocated lenses there was in this patient no diplopia. More careful examination, however, showed that while the object of fixation was seen single, objects at the periphery of the visual field were seen double. This distinction, Isakowitz thinks, offers a means in doubtful cases of ascertaining whether the lens is dislocated or not. Sohby reported a coloboma of the lens where the edge was a straight line and was unaccompanied by a coloboma of the other tunics, which he states is rare, as fifty percent. of the cases reported in literature are accompanied with such colobomata. In Sohby's case the coloboma was situated on the nasal side. The straight line type of cases is rare. Bock reported only one of this kind as against eighteen of the common variety. Iridodonesis is occasionally met with and various forms of cataract occur, viz: nuclear, central, total juvenile and senile, posterior polar, anterior and posterior cortical. A lens opacity may be localized in the colobomatous area. Corectopia and vitreous opacities have all in rare instances been observed. Subsequent to birth changes frequently take place, cataract formation being the most common. The lens while at first in its normal position may later become ectopic. Verderame in 1907 observed a case described by Christen in 1893, at which time both lenses were clear and in position. In 1907 both lenses were opaque and completely dislocated.

Even more uncertainty surrounds the genesis of coloboma of the lens than that of other colobomata. Collins' theory was mentioned incidentally in the preceding text. In a way supporting Collins' theory are the observations of Isakowitz and Wessely. The former noted a coloboma of the lens after a tear in the zonule. The patient was a blind boy of 18, who had had double iridectomy performed at the age of one year for adherent leucoma. Wessely was able to produce experimental coloboma in the growing eye by performing iridectomy on the eyes of new-born rabbits, eight to fourteen days old. This change which comes on gradually, in a week or two, after the operation, and resembles the condition in human beings, is due to operative injury of the zonule, allowing limited localized diminution of traction on the lens capsule and the consequent development of the anomaly.

Sobby raised the question as to whether the coloboma, and cataract which is so often associated with it, might not be the result of the same factor, viz: a constitutional disease. Hess thought that a coloboma of the lens might be due to abnormal persistence of some of the vessels of the lens sheath. The explanation which Hess applies to atypical iris coloboma can be equally as well applied to lens coloboma, typical or atypical. Hess attributed many anomalies to the persistence of strands of mesoblastic tissue. These strands may be the result of an atypical development of the mesoderm which connects the cavity of the optic vesicle with the surrounding cephalic plates and may contain vessels which supply the vascular capsule of the lens. These might mechanically interfere with the development of the lens and iris at

Anterior Section of Coloboma of the Ciliary Body. (After Bock.)

some particular point and such was probably the case in the microphthalmic eye with lens coloboma described by Hess. A like condition obtained in his case of iris coloboma, where the strand could still be seen in the full grown eye.

Coloboma of the ciliary body. Coloboma of the ciliary body is a frequent accompaniment of coloboma of the iris and choroid though it may be found as an isolated defect. As early as 1826, Erdmann from the apparent absence of the ciliary processes in a coloboma of the iris, concluded that a coloboma of the ciliary body was in all likelihood present also, which of course, cannot be accepted for the reason that in quite a number of instances this absence of the ciliary body has been shown to be only apparent. Those cases of coloboma of the ciliary body which have been carefully observed, have all been typically situated downwards, in the position of the fœtal cleft. It cannot be said, however, that atypical coloboma of the ciliary body may not occur. Future microscopical examinations of atypical coloboma of the iris and choroid

may show this condition to be present. Nuel and Leplat observed clinically a case of atypical coloboma of the iris and choroid in which no ciliary processes could be seen in the region of the iris coloboma. This, however, is no proof that they were in reality absent. Under the head of development it was stated that coloboma of the ciliary body is a normal condition in Cochin China fowls. The anomaly shows great variability in its form, size and arrangement. In the least marked form the defect present is assumed to be a rudimentary coloboma for the reason that there is an accompanying iris and choroid coloboma. In this instance it is simply represented as a pigmented or unpigmented stripe, extending from the middle of the ciliary body into the choroid. In more pronounced forms the circle of ciliary processes is interrupted below, in the middle line, by a cleft passing in a direc-

Coloboma of the Ciliary Body. (After Coats.)

Due to the insertion of the mesoblastic strand which replaces the anterior part of the vitreous; a large plaque of hyalin cartilage is seen below. m. Lens adherent to the mesoblast. h. Hypertrophied ciliary processes by the side of the coloboma. v. Ciliary muscle. (*Ophthalmoscope*. Oct., 1910.)

tion downwards and backwards so that an anterior notch is formed with a corresponding posterior rounded projection. The whole surface of the ciliary ring may be deviated from its normal frontal position to one backwards and downwards. The processes adjoining the cleft vary very much in size, being in some cases very large and so covering the defect that macroscopically it is not visible. In other cases they are much diminished in size and are attached to the edge of the cleft like feathers on a quill. In some of the cases giving this appearance there may be no actual or definite cleft. Furthermore, the coloboma may be covered by a yellowish body formed by the enormous hyperplasia of the unpigmented cells of the pars ciliaris. This formation often takes on a peculiar polypoid-like shape and projects backwards into the vitreous body. A more or less pronounced cleft

in the ciliary muscle may be present or be entirely absent. Alt discovered accidentally in a section through the middle of the ciliary body a coloboma which extended to the ciliary muscle, but did not involve it. The processes on each side showed little deviation from the normal. The floor of the coloboma was somewhat pigmented. The floor of the coloboma in most cases is covered with a loose, spongy and vascular connective tissue which may be raised into a crest containing areas of cilio-retinal epithelium. In two instances Bock observed complete absence of the ciliary body in a nasal and temporalward direction in connection with extensive colobomata in the lower part of the eye. An inward directed rudimentary coloboma of the ciliary body was described by Hess occurring in a case of nasal coloboma of the lens; the ciliary processes were retracted, thickened, irregularly stunted and distorted.

Coloboma of choroid and retina. These two structures are considered together since their association is so intimate. Von Ammon made the first recorded observation. In a large majority of the cases there is present at the same time a coloboma of the iris. Between thirty and forty cases, however, are on record where the iris was perfectly normal. Here as in other colobomata we speak of typical and atypical, referring to the usual situation of downward, or downwards and somewhat inwards as the typical type. Atypical choroidal colobomata are very rare. Upon examination of the fundus ophthalmoscopically there is seen a bright-white reflex from the colobomatous area due to the complete or almost complete absence of pigment. The coloboma generally has an oval shape with a rounded end situated near the disc. The defect may also assume a shield form. The long diameter is generally antero-posterior. The anterior end may reach to the ciliary body and is then usually indistinguishable with the ophthalmoscope. In other cases the coloboma is horizontally oval and may reach to and include the disc. The usual type, vertically oval, reaches, as a rule, to near the papilla, but in exceptional cases extends above it and surrounds it so that only by the difference in color and the convergence of the vessels, the situation of the papilla can be made out. The shape of the papilla is frequently a horizontal oval. The inferior portion of the disc often shows a depression even when the papilla does not lie within the coloboma. The horizontally oval colobomata are rare; a striking example was the case reported by Litten in which the defect measured 7 mm. by 3 mm. As a rule the edges of the coloboma are pigmented; the regularity of its borders is often interrupted either by patches of pigment which invade the coloboma to a more or less degree or by tongue-shaped areas of normal

fundus (Hirschberg). Spots of pigment or islands of normal fundus may be situated within the coloboma. Coloboma of the choroid is generally bilateral in the proportion of 2 to 1. It is said to affect the left eye to a greater degree than the right, and that when the condition is unilateral it is more often the left eye which is involved (Panas). Only infrequently is the level of the coloboma the same as the remainder of the fundus; almost without exception there is a marked depression of variable depth. This is shown by the difference in refraction and the parallactic displacement of the vessels. In a

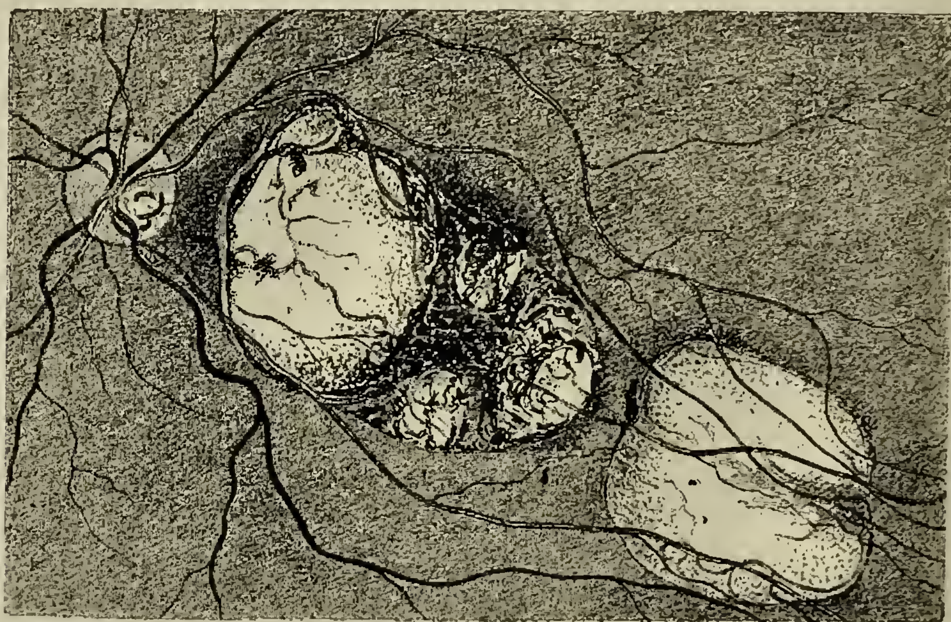
Coloboma of the Choroid. (After Haab.)

given case the depression may not be uniform but show areas of localized ectasiæ. Not infrequently a medium line or ridge divides the coloboma into two lateral ectatic halves. The color of the coloboma whilst usually white often shades off from a pure white. It may have a mother-of-pearl, bluish, yellowish, or even greenish appearance. The darkened areas often noticed are probably due to unsymmetrical ectasiæ in the floor of the coloboma. There are two systems of vessels in the region of the coloboma, viz: ciliary and retinal. The retinal vessels can be seen to be in direct connection with the other retinal vessels and may either be confined to the margins of the defect or be distributed over the entire coloboma. In addition to these there are observed numerous vessels which are branches derived from the short posterior ciliary vessels which on account of their great width and tortuosity resemble choroidal vessels; they are seen lying beneath the

retinal vessels, on the floor of the defect, after having penetrated the sclera and divided into numerous branches. Frequently these vessels make their appearance at the border of the coloboma. The first branches of the central artery may take a direction upwards and thus give one the impression that the fovea is situated above the disc and surrounded by the vessels (von Hippel). In typical colobomata the inferior vortex vein is often missing and the lateral ones are displaced outwardly. When the disc is involved in the coloboma other vascular anomalies are seen. The large colobomata which surround the papilla are often so wide that they extend into the region of the fovea. When not so large, the characteristic normal appearance of the fovea is frequently missing. Saemisch and Cohn, however, noticed an ophthalmoscopically normal appearance of the fovea. Anatomically a normal fovea has not been found (von Hippel). However, the good vision which certain cases show together with good fields proves conclusively that in cases where such are found, an approximately normal fovea must be present. In addition to choroidal coloboma there may be present in the same eye colobomata of the other parts, such as the disc and macula, together with old retino-choroiditic spots (De La Personne, Rieker). The vision, while occasionally good, is as a rule quite defective due either to the coloboma itself or to the accompanying defects such as the atrophic spots just mentioned, or anomalous shape, size or curvature of the cornea, microphthalmus, high myopia, opacities and coloboma of the lens, optic atrophy, etc. The cornea often has the form of a vertical ellipse with the lower end pointed. At times the cornea is remarkably small (microcornea). The defective shape gives rise to a high degree of corneal astigmatism. The refraction is usually considerably, and often highly, myopic due to the increase in length of the eyeball or the increased curvature of the cornea. Acuity of vision is generally reduced to 1/10 to 1/5, sometimes worse, sometimes better. Vision as good as 4/5 is recorded by Saemisch. The field of vision shows a scotoma corresponding to the coloboma but rarely so great in extent. Formerly it was held that the defect in the field was indicative of the absence of retina in the coloboma; this has been proven an erroneous conclusion. Careful examination will often show that the colobomatous area possesses light perception. This was demonstrated by Schmidt-Rimpler; Benson found in the field corresponding to the coloboma no actual scotoma but only a diminution of vision at the periphery. Haab demonstrated the perception of red and blue. Where the macula is involved it may be very difficult to determine a field.

Strabismus and nystagmus are often present. Photophobia is

sometimes seen but it is doubtful if it is a result of the choroidal coloboma. Besides the anomalies previously mentioned persistent pupillary membrane and cataract are occasionally present. Concomitant bodily defects are microcephaly, hare-lip and deaf-mutism. The rarity of atypical choroidal colobomata makes their recital interesting. Van Duyse collected the following cases. 1. With coloboma of the iris. Steinhein found also right anophthalmia, left internal coloboma of the iris, internal coloboma of the choroid including the disc; Nuel and Le Plat, left external coloboma of the iris, slight coloboma of the disc, external choroidal coloboma three disc diameters from the



Extra-Papillary Coloboma of the Choroid. (After Lindsay Johnson.)

papilla; Frost, external coloboma of the iris and of the choroid. 2. Without coloboma of the iris. Pflüger, bilateral external colobomata of the choroid involving the discs with choroido-retinal lesions; Nuel, right external coloboma from disc to macula; Lang, coloboma up and out with hydrophthalmus; Randall and de Schweinitz, left internal coloboma with translucent greenish projection into the vitreous; Lindsay Johnson, coloboma of the optic nerve, inferior external coloboma of the choroid ("extra-papillary coloboma"); Pfanmüller, coloboma external to the macula; Rindfleisch, upwards, ectatic extra-papillary coloboma; von Hippel, bilateral coloboma up and out, with interstitial keratitis and anterior synechiæ. To the above may be added the case of Derby, right eye normal, left eye small, hyperemic papilla almost completely surrounded by opaque nerve fibers, opacities on anterior lens capsule; above the disc and separated from it was a

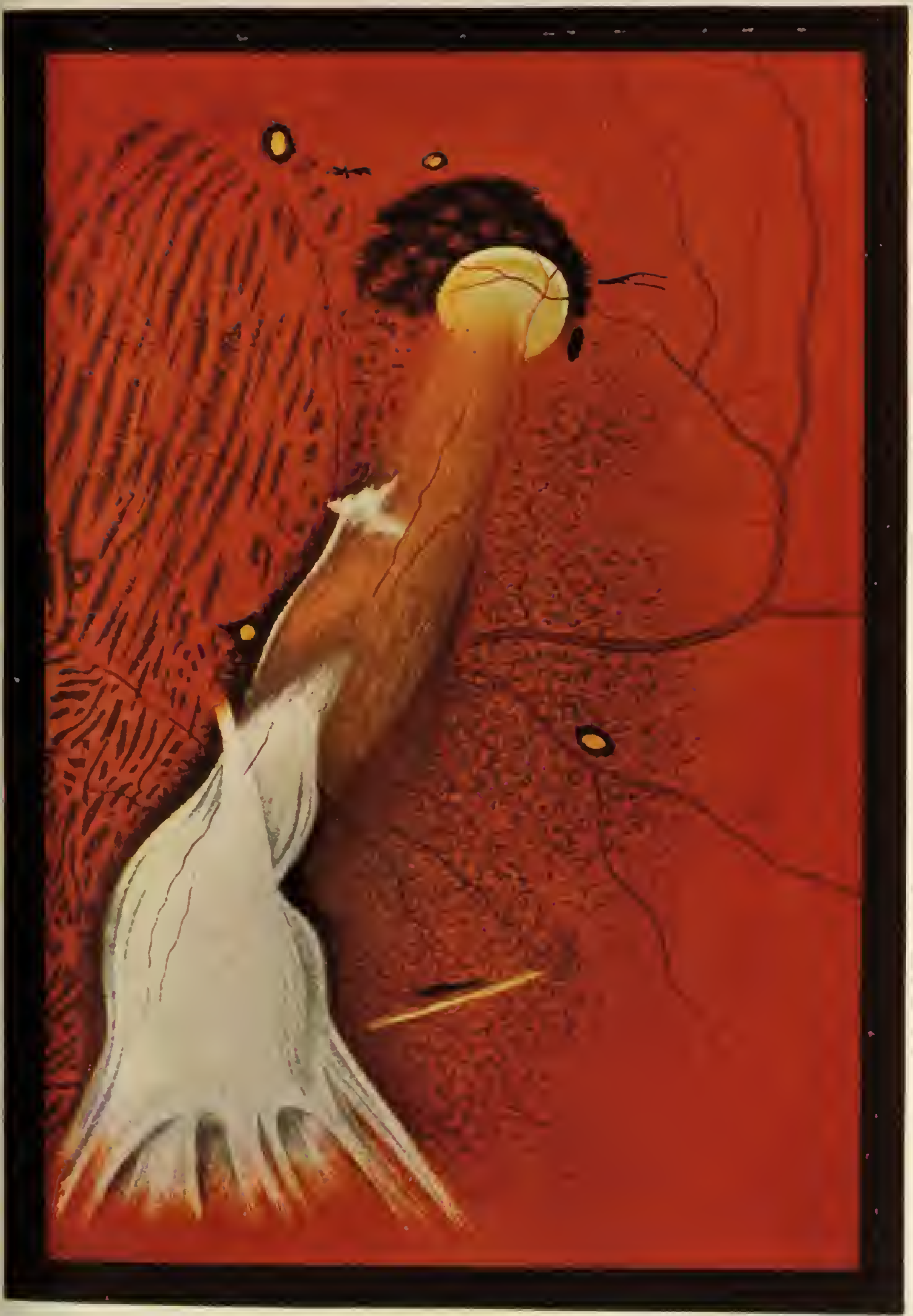
rounded coloboma of about three disc diameters and with a depth of four or five diopters. Meissner reported a case with aplasia of the optic nerve, rudimentary development of the choroid, retina and pigment epithelium in the region of the fœtal cleft, atypical coloboma of the retina; there was also pigment epithelium situated in the ciliary body, double hare-lip and cleft-palate. Botteri reports a monocular coloboma of the choroid, O. S., directed nasalwards, in the middle of which coursed the remains of Cloquet's canal. Bradburne, atypical annular bilateral choroidal coloboma simulating staphyloma posticum, a grayish-white ring, a disc-and-a-half wide, surrounded the disc.

Coloboma of the Choroid and Optic Nerve. (After Haab.)

Apparent complete absence of both choroids except at the macula have been reported by Tatham Thompson, Landmann, and Alexander. Atypical coloboma of the iris with typical coloboma of the choroid is very rare. Parsons mentions three genuine cases, those of Mittlestädt, Von Reuss and Hess. Atypical choroidal coloboma has not been examined microscopically, whereas the typical variety has been frequently examined, but it has been difficult to draw binding conclusions from these findings. Of the greatest importance is the condition of both layers of the secondary vesicle. The early conception that these must of necessity be missing was soon disproved. Quite the reverse is

true. The layers while present are usually very much thinned and badly formed. The pigment epithelium is generally missing over the whole coloboma though it may be present in patches. In some instances areas of pigment epithelium cells are present and only the pigment itself is missing. In the well-known case of Pause's the pigment epithelium was present throughout the whole coloboma, the pigment only being absent. As a rule the pigment epithelium diminishes from the periphery towards the center, gradually loses its pigment until all is lost, the cells become smaller, rounded and finally can no longer be recognized. The pigment epithelium may give origin to an unpigmented tissue whose cells lose all similarity to the normal cells, and whose real histological character can only be determined by a searching microscopical examination. A complete absence of the inner layer of the secondary vesicle is very rare even in the more pronounced grades, the membrana limitans interna can be demonstrated, binding the edges of the coloboma together (von Hippel). Various authors (Haab, Pause, Mannhard, Bach), have asserted that the retina in their cases was of plainly recognizable structure in the whole coloboma. When found it is usually much altered. In Pause and Bach's cases it was stated to be normal. von Hippel took exception to these findings on the ground that in all the cases meridional sections were made and that therefore a small median cleft might have been overlooked. Between absence of the retina and a normally present one, all conditions are possible; irregularity of the layers, distortion of the layers particularly the nuclear layers in which rosette formations occur similar to those in glioma; displacement of the rods and cones, formation of cystic spaces, increase in the supporting substance, absence of rods and cones, fusion of the sclera with the retina. Haab, Becker and Van Duyse observed a doubling of the retina, the edges being turned inwards. The turning outwards of the edges is a normal condition in the ciliary colobomata of Cochin China fowls (Lieberkühn). In the great majority of cases the choroid is absent in the region of the coloboma but there are some few cases where anatomical examination revealed its presence though altered in structure. The lamina fusca is said to be usually present. The choriocapillaris is absent. An atrophic and unpigmented choroid was noted by Hirschberg. Pinto could follow it for a distance into the coloboma where it became transformed into scar tissue.

Deutschmann and Bock found a choroid altered by inflammation. Pause saw a completely normal choroid. This case was not examined ophthalmoscopically during life so what sort of an ophthalmoscopic picture it would have presented is a matter of conjecture. Usually the choroid ceases at the coloboma margin which is thickened and infil-



A Fundus Anomaly; Entrance of Retinal Vessels Covered by Tissue Mass.—(BERGMANN.)

trated with round cells. At the margins the choroid, retina and even the sclera are often fused together. Where the choroid and retina are not recognizable as such there may be found a delicate connective tissue membrane similar to the lining of a posterior staphyloma in a highly myopic eye. The usual lining of the coloboma is a thin fibrous membrane possessing no resemblance to either retina or choroid. The condition of the retina and choroid may to some extent depend upon the condition of the sclera. The latter in rare cases may be nearly normal, usually it is thinned, much so in the ectatic areas; the median

Coloboma of the Choroid, Retina and Optic Nerve. (After von Hippel.)

raphé at times shows a thickening. The thinning is often at the expense of the inner layers. Deutschmann described a thickening of the sclera in the colobomatous area. The transition from normal to thinned sclera is gradual at the anterior and posterior borders, whereas the lateral borders of ectatic colobomata are at times much thinned and thrown into ridges and folds giving an imbricated or tiled appearance, the gaps and spaces of which are filled with a spongy fibrous tissue. In other highly ectatic colobomata a formation similar to orbital cysts takes place. A median raphé is sometimes present on each side of which lie deep ectatic excavations. This raphé may be bifurcated posteriorly (Bock) and single anteriorly and contain blood-vessels.

The margins of the secondary vesicle may sometimes be demonstrated at the edges of the raphé, as a comb-like structure (Bock).

Vascular connective tissue strands resembling the hyaloid artery or its branches are sometimes seen extending forwards to the posterior lens capsule where branching takes place and thence may reach to the ciliary body and sclero-corneal zone (Hess, Hänel, Bach, Pinto, Tartuferi, Eversbusch). In many cases there have been found appearances of recent or old inflammation. In human eyes atrophic, choroidal spots in the region of the coloboma have been noticed by Bock and Van Duyse. Apparent inflammatory changes were noted by Thalberg, Wood, Deutschmann and Höltzke. In four weeks' old rabbits with bilateral congenital iris and choroidal colobomata, a high grade sclero-choroido-retinitis existed in the region of the colobomata (von Hippel). Colobomatous eyes are very prone to inflammatory changes and unless such eyes are examined soon after birth it is manifestly impossible to decide in the human being whether these changes were of post-natal or ante-natal origin.

Coloboma of the Macular Region. (After Haab.)

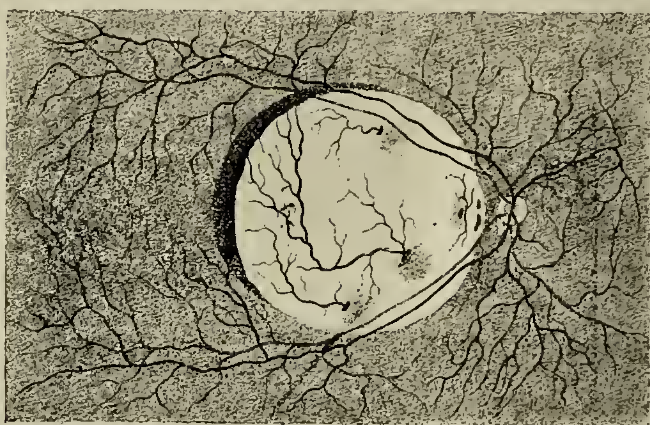
Coloboma of macula. The so-called macular coloboma is a rare condition. It is a partial atypical coloboma. Most of the cases have been unilateral, possibly a fourth of the total number are bilateral. In 1893 Bock collected records of 31 cases to which he added others. At present the recorded cases number about fifty. The anomaly involves the choroid and retina. The formation can have nothing to do with the fœtal cleft since the macula is not developed in the cleft. Paramacular and extra-papillary colobomata where the macula is free, in a strict sense should not be classed under this anomaly. Ophthalmoscopically there is seen a white or yellowish, sometimes mother-of pearl colored reflex in the macular region. The involved area is generally of a horizontal, oval shape; rarely is it circular (Kimpel), or angular. The edges are usually distinct and sharply-defined and the borders are often strongly pigmented with an outlying zone of yellow-

ish color. The horizontal or long diameter varies from 1 to 10 P. D., the average being 3 P. D. The vertical diameter is from 1 to 3 P. D., very rarely it is more. The level of the defect is very variable. In a majority of the cases there is a pronounced ectasia, varying from 1 to 6 D. The maximum of 10 D. is recorded by Bock. The ectasia may not be the same in all parts of the coloboma. In a small number of cases no ectasia or a minimum amount was present. The surface of the coloboma may show scattered areas of black pigment. Retinal vessels are to be seen in the majority of cases though the vessels are diminished in number and size. Less often are the choroidal vessels visible. These formed in the individual cases of Wiethe and Johnson a net-work of vessels resembling a ''nævus'' of the choroid. The case reported by Landmann, while the exact reverse of the condition under discussion, is of interest in this connection because of the presence in the macular region of a group of small and large vessels forming a fluffy plexus and filling an area somewhat larger than the disc. Landmann's case was one of symmetrical congenital absence of the choroid and retina, except in the macular area. In Kimpel's case large branches of the posterior ciliary vessel were seen emerging from the floor of the coloboma. The retinal vessels after traversing the coloboma for a distance may pierce the floor and disappear. With the exception of the case of Michaelson, in which there was present microphthalmus, coloboma of the nerve and persistent pupillary membrane together with a macular coloboma, the eye affected is usually of normal size. It is stated that where the condition is unilateral, the left eye is most commonly affected. Among anomalous conditions which are sometimes found simultaneously present, are conus down or out, typical coloboma of the choroid, atrophic choroidal spots in different parts of the fundus, circum-papillary, sharply-defined, pigmented zones such as are seen in marked myopia, medullated nerve fibers, aniridia, persistent pupillary membrane, coloboma of the optic nerve, microphthalmus and microcephaly. All of these coincident anomalies are rare. Silcock reported an instance where a persistent hyaloid artery was attached to the middle of the coloboma and extended thence to the back of the lens. Nystagmus and strabismus are at times noted. The refraction is variable, the same is true of the acuity of vision and the fields. Frequently it is impossible to satisfactorily determinate the field. About three-fourths of the cases have myopia which may be entirely independent of ectasia of the coloboma (Schnabel, Kimpel and Bock). Hypermetropia is next in frequency, being found as high as 12 D. (Schmidt-Rimpler).

In recent years Hansell and Reber in this country have reported

cases. Hansell's was bilateral and the defect nearly circular and symmetrical. The remaining parts of the eye were normal, except the refraction which was mixed astigmatism, the prevailing defect being hyperopic. There was a moderate degree of squint and marked horizontal nystagmus. Reber's case though deviating from the usual type probably represented a congenital anomaly and should be recorded therefore amongst the cases of unilateral coloboma.

Emmetropia is unusual. Vision may be fair but is usually very much reduced. Where the coloboma is ectatic the vision is especially bad. The fields are variable and hard to determine. Absolute scotoma has been noted by Schnabel, Michaelson and Bock, the case of the latter showing a vision of 6/6. The scotoma is often relative. Katalsky described a ring scotoma in the center of which was normal vision.

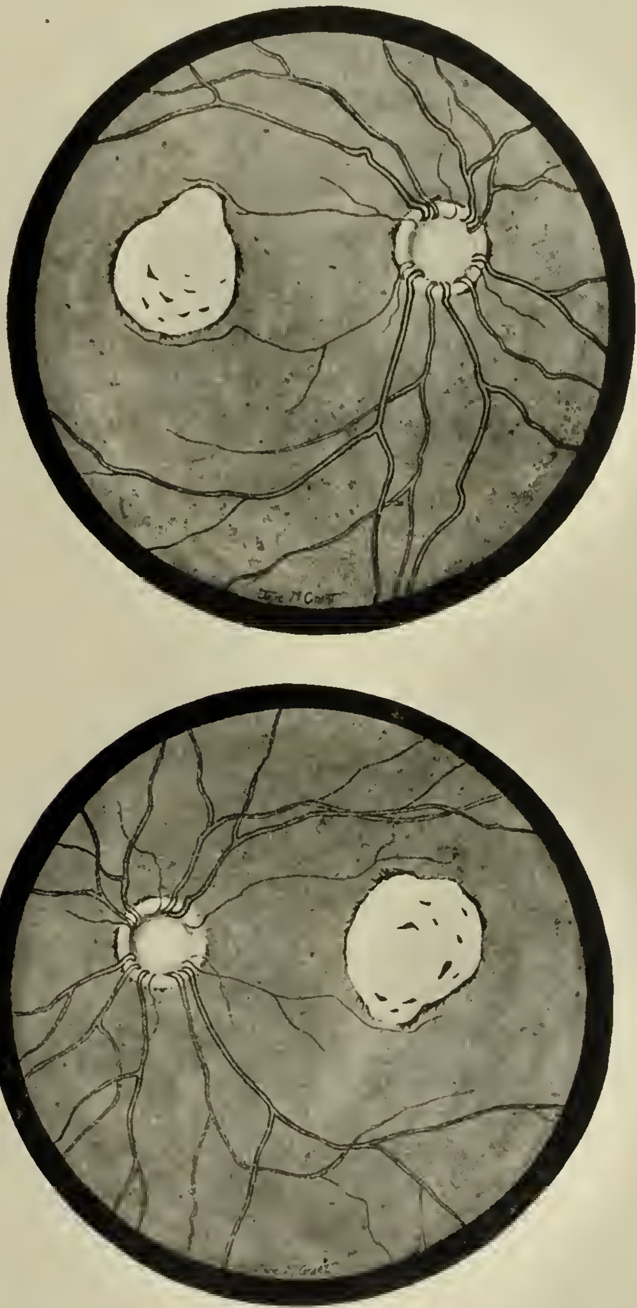


Central Coloboma of the Macula. (After Kimpel.)

In a case of Van Duyse's a relative scotoma was present, which was greater than the corresponding area of the coloboma, and in the nasal part of the field there was a complete failure of light perception. In Bock's case with a central scotoma and 6/6 vision, this good vision could only exist according to Von Hippel with a peri- or paracentral scotoma. The clinical picture would lead us to assume that the pigment epithelium or at least the pigment was absent. The absence of choroidal vessels also speaks against the presence of the choroid, or for its presence only in a rudimentary state. We would expect the retina to be present in a large part of the colobomatous area, otherwise the scotoma would be larger than is often clinically found. The anatomical investigations which have been made show to what extent these suppositions are true.

Microscopical examinations have been made of macular colobomata by Bock, Zimmermann, Hess, Van Duyse and Deyl. The retina and choroid may be entirely absent, or one or both incomplete so that a

thin membrane may cover the surface. Bock's case was somewhat of this nature, the retina formed a thin membrane with remains of the nuclear layers, the choroid and pigment epithelium being absent.



Bilateral Coloboma of the Macula. (After Hansell.)

In Zimmermann's case there was absence of the choroid and retina. In Deyl's case the retina though present was much attenuated, the outer layers disappearing at the edges. The choroid existed in a changed form resembling scleral tissue with pigment deposited about

the vessels. In the case of Hess the choroid was absent, the retina much thinned and reduced to a fine fibrous membrane. The sclera was reduced to one tenth its normal thickness in the ectatic area. Full consideration cannot be given to Van Duyse's case as it occurred in a cyclopic eye. The choroid and pigment epithelium were missing and the retina was not developed fully.

H. S. Gradle (*Ophth. Record,* October, 1913) has examined several rare, nearly identical anomalies of the *macular retina.*

In one of these the pupillary reactions to light and accommodation were normal. Pupils dilate well under homatropine. In the macular region of the fundus can be seen the following condition:—Right—The fovea is comprised of a slightly oval area about the size of the papilla, of a dark red color, speckled with very fine black points. In the center is an exceptionally well demarcated, discoid, yellowish-white, foveal reflex. The dark red fovea is surrounded by a grayish red zone, sharply demarcated on the foveal side and gradually fading into the surrounding normal fundus toward the periphery. The width of this zone is about one-fourth of the narrowest diameter of the fovea. The foveal edge is clean cut, and seems to be as perpendicular as are the edges of a glaucomatous cupped disc. The papillo-macular artery, in passing through the light zone, is hazy, but reappears sharp at the edge of the fovea, bends backwards and becomes lost in the depths of the macula. The floor of the fovea is uniform, and seems to be about one-third of a millimeter deeper than the surrounding lighter zone. It can be easily seen that this zone is composed partly of vague restless light reflexes, partly of a delicate, grayish opacity situated in the innermost layers of the retina. This view is corroborated by the fact that the branches of the foveal artery bend sharply in passing from the gray zone to the dark red fovea, and that there is a distinct parallax of the gray zone contrasted to the foveal background. Although the light reflexes are more intense with a narrow pupil, they are still visible with a mydriatic.

The abnormality of the light reflexes cannot be explained easily. As the refracting media of the eye are normal, we must look for their peculiarities in the macula proper. The whiter aspect of the central reflex is probably a contrast color, due to the unusually deep red of the fovea proper, which color is in turn a sequence of the unusually abrupt limiting walls of the fovea. The restless gray reflexes, partly comprising the grayish zone around the fovea, must be dependent upon the abnormal thickness and semi-opacity of the superficial retinal layers. We know that these limiting reflexes are dependent partly on the size of the pupil and partly on the mirror effect of the transparent

retina with its posterior coating of black pigment. These reflexes, hence, lie well anterior to the retina and their exact location in the vitreous chamber can only be guessed at. However, a disturbance of the macular retina is followed by a disturbance, or disappearance, of these reflexes as evidenced in a severe central chorioiditis.

The grayish zone immediately around the fovea is due partly to an increase in thickness of the innermost retinal layers, partly to an opacity of these same layers. That the relative height of the internal limiting membrane of the retina above the floor of the macula is greater in these eyes than in the normal, can be shown by direct ophthalmoscopic measurement. That the increase in thickness lies in the innermost layers of the retina can be deduced from the appearances of the temporal branches of the foveal artery. Before entering the gray zone, the artery has a normal appearance. Immediately after its entrance, the outlines of the vessel lose their sharpness of contour and the color becomes somewhat muddy. These changes increase as the vessel passes through this zone and suddenly upon its emergence at the foveal border, the vessel stands forth sharply in all its clearness and beauty of color. Then it dips as though bending over the edge of a cup, and becomes lost in the floor of the macula. We know that the retinal vessels lie in the depth of the nerve-fibre layer and in the superficial and middle areas of the ganglion-cell layer. Hence, this cloudiness is certainly due to an abnormality of the layers lying internal to the vessels, i. e., the nerve-fibre and ganglion-cell layers. Perfect fixation of the macular retina and subsequent histological examination is so rare that the normal macula and its relationship is still a problem incompletely elucidated. However, some histological examinations have shown increased thickness of various retinal layers. Again, Elschnig describes an albinotic fundus with complete lack of development of the macula. Hence, one is justified in assuming a circumscribed local thickness of various local layers.

In the normal macula, the ascent from the floor of the fovea to the normal retinal level, or as Salzmann terms it, the clivus, is a very gradual one and cannot be measured ophthalmoscopically. In this condition, however, the clivus is probably very abrupt, in fact, so much so, that the walls are nearly perpendicular to the normal macular floor. This is shown by the suddenness with which the vessels plunge into the depths of the fovea, closely resembling the sharp bend made by vessels descending into a glaucomatous cupped disc. This would lead to the supposition that the macula is depressed. But such is not the case. For the retinal pigment epithelium is clearly visible in an

otherwise normal macular floor. The macular rods and cones are evidently well developed, for central vision through a pinhole disc is perfect. Moreover, there are none of the appearances of a coloboma, for such would be the condition were the macula depressed.

Thus, we have apparently a condition of "hole in the macula." In reality, however, the macular floor is normal, though surrounded and sharply demarcated by unusually abrupt walls of the retina whose innermost layers have undergone a considerable increase in thickness and have lost some of their transparency. This does not correspond with the "hole in the macula" first described by Haab and later mentioned in the various text-books.

Coloboma of the zonule of Zinn. Defects in the zonule occur chiefly where defects of the ciliary body are present. Bock found the zonule missing in cases of coloboma of the lens investigated by him. The shape of the defect is generally triangular with the base at the ciliary border and the angle directed towards the lens border. An irregular arrangement and course of the zonular fibers, as occurs in rudimentarily developed coloboma of the ciliary body, may be looked upon as suggestive of a zonular coloboma. The fibers at the margins of the coloboma may be appreciably thickened. As one would expect the zonular fibers are often missing in the region of a coloboma of the ciliary body, but this is by no means always the case, as the zonule has been found intact where the ciliary processes were completely missing, or where the ciliary body was poorly developed. This latter circumstance would seem to conflict with the Treacher Collins theory of the development of the zonule.

Coloboma of the nerve. In the consideration of coloboma of the nerve, the two conditions of optic nerve coloboma and optic nerve sheath coloboma are taken together. Cosmettatos prefers to use the designation "coloboma at the entrance of the optic nerve," as suggested by von Hippel, as being more exact. He points out that anatomical examinations have shown that as a rule the optic nerve and its sheaths are not implicated, but the deformity is situated entirely in the membranes forming the entrance of the optic nerve. He described three instances of the condition usually known as coloboma of the optic nerve in none of which did the papilla show any abnormality. Coloboma at the optic disc is a rare anomaly, Vossius giving the ratio of three in twelve thousand patients. Saemisch up to 1891 collected forty-eight cases. Von Hippel, in 1900, stated that approximately fifty cases have been described. Since then cases have been described by Gilbert, Coats, Van der Hoeve, Zade, Cosmettatos, Hird and others. From the ophthalmoscopical picture it is impossible to say exactly

whether one is dealing with a coloboma of the nerve or its sheath. The clinical appearances are very variable; as usually seen there is apparently a great increase in size of the disc and its shape is irregular. The deep-pit-form which it assumes often measures several times the diameter of the normal disc. There is a partial or complete ectasia of the surface of the pseudo-disc, as a rule deepest in the lower part. Small secondary excavations are frequently present in its floor. The

Coloboma at the Nerve-Head with Normal Vision. (After Van der Hoeve.)

retinal vessels leave the depths of the defect variously arranged and bend sharply at its overhanging edge. The coloboma is pearly-white, except at its upper portion, representing the situation of the optic nerve tissue, which is of an ill-defined, pinkish color. As a result of shadows the localized ectatic areas may appear grayish. The shape is irregularly round or vertically oval. The classification of Caspar with regard to the arrangement of the vessels is generally adopted. He divides them into three groups: 1. The lower part of the coloboma is most deeply excavated and the vessels spring from it. Their general direction is upwards so that the vessels which are to supply the lower part of the fundus must make a sharp bend downwards over the deeply excavated lower border. Those vessels destined for the upper

part of the fundus take a direct course upwards over the less excavated upper border. 2. The vessels emerge with somewhat of their normal arrangement either from the center of the coloboma or from a point a little above the center. 3. The vessels emerge separately at some distance from the center of the excavation or appear at the edges around the whole circumference. In the latter instance the retina appears to be entirely supplied with cilio-retinal branches. It is usual to make a distinction clinically between "coloboma of the optic nerve" and coloboma of the choroid adjacent to the nerve. Coats states that in the latter the defect has a more or less triangular shape as is usual in colobomata of the choroid in other situations and that "though it may touch, encroach on or even engulf the papilla, yet the boundaries of the latter are fairly distinct and separable from the floor of the colobomatous area." With "coloboma of the nerve" it is different as an enlargement and pitting of the nerve is simulated. However, the pinkish color in the upper part of the defect and arrangement of the vessels give a clue to the probable point of entrance of the nerve fibres. It may sometimes be impossible to tell the probable situation of the entering nerve fibres as the disc appears to be replaced by a deeply excavated area, equal in size to ten or twenty times the diameter of a normal disc. The vision varies between absolute amaurosis and normal. As a rule it is much reduced. In Caspar's case where there was no vision there existed a retinitis pigmentosa with thread-like retinal vessels. Van der Hoeve's case was of great interest. Vision of the right eye was 5/4 but a routine examination showed a coloboma of the optic nerve measuring nine disc diameters. The field generally shows a defect. In Von Nieden's case the defect was in the upper part. Van Duyse found the field concentrically contracted. Van der Hoeve detected a large scotoma corresponding to the entrance of the optic nerve. The outer limits of the field were normal as far as white was concerned but the color fields showed a deficiency above. In the left eye of the same patient there was a coloboma of the lens, choroid and optic nerve with a large defect in the visual fields both for white and colors.

Strabismus and nystagmus are sometimes present. Coloboma of the nerve is present in twenty per cent. of the cases of microphthalmus, and once was observed with a very small cornea where the eyeball itself was of normal size (Von Hippel). Other congenital anomalies sometimes met with are persistent hyaloid artery, opacities of the lens, lenticonus, coloboma of the iris and choroid, macular coloboma, atrophic choroidal spots, corectopia, coloboma of the lens, opaque nerve fibres and remnants of the posterior sheath of the lens and anen-

cephaly (Coats). Both typical and atypical iris and choroidal coloboma are seen. A typical choroidal coloboma may or may not enclose the disc. Anatomical investigations concerning coloboma of the nerve have been made by Von Ammon, Liebreich, Hess, Van Duyse, Manz, Bock, Ginsberg, Bach, Görlitz, Elschnig, Parsons and Coats. The latter observer reviewed twenty-six cases reported in the literature and described three cases of his own.

The most prominent anatomical feature is an enormous enlargement of the scleral foramen in which the pigment epithelium and choroid are missing and are replaced by connective tissue. In this area the retinal elements, while more or less altered in appearance, are yet plainly demonstrable. The localized areas in the walls may be so ectatic as to form a large cyst (Bock, Görlitz, Van Duyse), in this manner forming an intermediate stage in the production of microphthalmic cysts (Parsons). In the differentiation between "coloboma at the nerve entrance" and other conditions which give a similar opthalmoscopic picture, Coats called attention to two important points: 1. The relation of the intervaginal space to the ectasia. A coloboma of the optic nerve will show an ectasia related to the inner or pial portion while coloboma of the choroid will show an ectasia related to the outer or dural part. 2. Absence of the central vessels or their atypical development. Their absence is proof of an atypical development but does not prove the existence of a coloboma as the fœtal cleft may have closed normally without enclosing the vessels, the nerve in other respects being normal.

On the other hand a coloboma is not excluded by the presence of the vessels within the nerve as the mesoblast carrying the vessels may have entered in the normal way and the cleft failed to close either because of undue persistence of the mesoblast or from some other cause. It is therefore very difficult to make a sharp distinction between coloboma of the nerve and coloboma of the choroid adjacent to the nerve. In fact the two may occur in combination. Coats further states that a distinction between "coloboma of the nerve" and "coloboma of the adjacent choroid," while reasonable on clinical grounds cannot be maintained on pathological. The ophthalmoscopic difference depends chiefly on the amount of ectasia. He divides the cases into three groups as follows: 1. Those in which the defect is a coloboma of the choroid beneath the nerve, the nerve itself being normal and only passively taking part in the deformity. 2. Those cases in which the lesion is a coloboma of the choroid and nerve. 3. Those in which the lesion is a coloboma of the nerve alone, the adjacent choroid being normal. Groups one and two are considered together

by Coats. The least marked degree of this form of coloboma is a small, snared-off pocket containing distorted retinal elements (da Gama Pinto, Bach, Elschnig). Cystic spaces are often present in its depths. The floor is somewhat sunken, the central vessels make a slight bend in crossing it. In the more pronounced types the defect is more extensive and ectasia of the colobomatous area is present. The coloboma is nearly always at the lower border of the nerve entrance, the lower attachment of the lamina cribrosa sinks backwards, the upper part retaining its normal relations and as a result the lamina is directed downwards and backwards. The papilla is also displaced and looks downwards. "Whether the coloboma is in the lower part of the papilla or in the choroid beneath it, the nerve will be impinged upon by the excavation from the lower side and will become stretched out over the upper wall of the cyst." The vessels may enter normally in the center of the disc. If outside the nerve, the proper retinal vessels are replaced by posterior ciliary vessels which run in the outer sheath and vaginal space and pierce the floor of the coloboma.

No special set of vessels may be differentiated for the retina which then receives blood extraneurally from the cilio-retinal vessels which enter all around the circumference of the coloboma. This constitutes Caspar's third group. This distribution has not been proven microscopically. One of Van Duyse's cases is analogous. This condition may have been present in some cases where the vessels were absent from the interior of the nerve but not recorded as being found beneath it. Group 3. Coloboma confined to the nerve is a very rare defect. Coats states that besides his own cases there are but three undisputed examples to be found in the literature (Ginsberg, Görlitz and Von Hippel). Ginsberg's case was in a rabbit and was in the form of a deep excavation. In Görlitz's case there was no excavation, only a defect in the lamina cribrosa filled up with nervous tissue. In all three cases of Coats' a true coloboma of the nerve alone was present, the adjacent choroid being normal. The nerve entrance was of normal dimension and all the abnormalities were within its boundaries. A pocket of distorted retina passed through the lamina cribrosa and hollowed out of the nerve leaving the terminations of the choroid, sclera and intervaginal space intact, and in their normal relations to one another. Two of the eyes examined by Coats were associated with anencephaly. Elschnig described the anatomical findings in five cases of coloboma at the disc, two with rudimentary cysts. He noted an ingrowth of retina around the edge of the lamina vitrea at the disc. He thought that inferior coloboma (typical) is the result of faulty closure of the fœtal cleft when the retina is absent over the affected

area. Kundrat suggested that a typical coloboma could be explained by a defective development of the mesoblast which forms the choroid and sclera, which defective development in itself is due to an active over-proliferation of the lips of the secondary vesicle. Caspar attempted to draw conclusions as to the structure of colobomata of the nerves from the peculiarities in the course of the central vessels. Von Hippel showed that clinical observations gave no exact information as to the topography of the nerve and its sheaths. Anatomical observation showed that in many of the cases of so-called nerve coloboma there existed really only an ectatic coloboma of the choroid or a beginning orbital cyst and that there was no actual defect of the nerve or its sheath. Caspar explained all three groups by more or less marked anomalies in the closure of the fœtal groove. In the third group the edges of the groove meet only at its lower margin. Thus the nerve has the form of a tube which expands as it runs forward to form a hollow cylinder. The central vessels run along its wall after dividing into branches. The failure of the nerve cleft to close may be due to one of two causes, firstly, over-development of mesodermal tissue enclosed in the nerve, or, secondly, a defective formation of its anterior endoptic termination, the result of insufficient pressure of the cephalic plates which surround it and normally bring about its complete closure. Van der Hoeve concludes that whether these anomalies are to be considered as ectatic colobomata or as colobomata of the nerve sheath, they are caused, like defects of the iris, choroid and ciliary body, by atypical formation of mesodermal tissue in consequence of disturbances in the tissue of the cephalic plates surrounding the optic vesicle. The nature of these disturbances is as yet unknown, but reference is made to the experiments of von Hippel on rabbits, who has shown beyond a doubt that they may be hereditary. Von der Hoeve's patient with coloboma of the nerve had a sister with coloboma of the iris in the left eye and his mother had a double coloboma of the iris. He thinks these findings support the theory of heredity.

Fuchs' coloboma. (Synonyms—Congenital crescent, Inferior staphyloma, *Conus nach unten, Cône inférieur, Cône sous-papillaire.*) Fuchs' coloboma is a small crescentic defect of the choroid at the lower border of the disc not unlike a myopic crescent except in its position. This is the definition given by Lang and Collins in Norris and Oliver's *System.* Other observers take a different view. In fact a great diversity of opinion exists with regard to the true explanation of "congenital inferior crescent." Quite a number of observers contend that the white crescent below the disc really represents a minimal type of coloboma of the choroid. Others state that it represents a minimal form

of congenital coloboma at the nerve entrance and, in support of this, point to the misshapen horizontally oval form of the disc. The disc often appears as if it were twisted around its antero-posterior axis, so that its long axis is horizontal, and its physiological cup is directed downwards. The course of the vessels is abnormal; they usually enter in a downward direction, the lower branches continuing thus, while the upper soon curve sharply upwards over the disc margin to reach the fundus. Where the crescent is superior the vessels have the remarkable appearance of being shot vertically from the disc, and the

Coloboma of the Papilla. (Van Duyse.)

lower branches curving sharply downward to reach the fundus. If the crescent is nasalward the disc is fore-shortened in the vertical plane and the vessels are directed strongly inwards. A constant and interesting feature noticed by Worton in all his cases was a bleached or semi-albinotic state of the fundus in its lower and inner part. He thinks this appearance is due to some lack of pigmentation in the layer of hexagonal epithelium of the retina and attenuation of the choroid due to stretching. Over such areas some impairment of retinal function is brought out by color tests. Where crescents exist bilaterally the condition may be more pronounced on one side than the other, or the position of the crescent may differ considerably in the two eyes. Commenting on the concomitant conditions in blue sclerotics, Harman stated that it was noteworthy that in nearly all of those subjects

in whom the refraction was worked out a considerable degree of astigmatism was found, the discs were oval, and Fuchs' colobomata at the lower edge were found.

The course of the vessels is abnormal; they usually enter in a downward direction. Coats states that as the condition occurs relatively often in hypermetropic eyes, it is hardly probable that it should be due to a stretching of the ocular tunics. The occurrence of astigmatism is frequent. In thirty cases studied by Worton, astigmatism was found to be present in more or less degree in all the eyes affected, and in the majority of the cases (63.6 per cent.) was made up of combined corneal and lenticular astigmatism. In 22.7 per cent. the astigmatism seemed to be wholly corneal and in the remainder (13.6 per cent.) wholly lenticular in character. Liebreich (1859) first thought of a possible connection between Fuchs' coloboma and choroidal coloboma. The idea that defective closure of the fœtal cleft was the cause of the anomaly was furnished by Jaeger in 1861. Later Schnabel supported this theory. Both these observers saw this condition in highly hypermetropic eyes and also noted the anomaly on the temporal side in the new-born. Fuchs accentuated the necessity of differentiating between congenital crescents and the acquired form which is due to myopic choroidal atrophy. Elschnig found appearances virtually identical with those seen in myopia in the anatomical and microscopical examination of three cases and considered that they are produced in a similar manner, viz., by stretching of the ocular tunics at the posterior pole and consequent pulling away of the choroid from the disc margin. He attributes the stretching to an inherent weakness or lack of consolidation of the tissues in the line of the fœtal cleft, allowing them to give way before the normal intra-ocular pressure. Schnabel also held the opinion that inferior conus and coloboma at the nerve entrance should be distinctly and separately classified. Elschnig's microscopical examinations showed that the scleral promontory was rounded off instead of projecting in a sharp spur at the nerve entrance; the choroid, membrane of Bruch and nuclear layers of the retina ended some distance from the nerve entrance. Above the nerve, however, the sclera and choroid projected over the nerve entrance in the form of a sharp spur. The inter-vaginal space instead of being wider on the side opposite the conus, as is usual in myopia, was widest on the same side as the conus. Elschnig thought therefore that inferior conus is not strictly a form of coloboma at the nerve entrance. Coats thinks that it is possible that in some obscure and indirect manner the fœtal cleft influences the defective formation of the sclera and choroid below and that this would account for much greater frequency of conus

downwards than conus inwards or upwards. Elschnig stated that in his cases the thinness of the sclera was out of proportion to the amount of stretching and must consequently have had a congenital basis. Coats explains inferior conus as follows: The horizontally oval shape of the disc results from the pull upon it from below, due to the stretching and corresponds with the vertically oval form so often seen in the myopic disc. The downward direction of the vessels results from the same cause and corresponds with the temporal direction of the vessels in the myopic eye. The presence of the anomaly in emmetropic and hypermetropic eyes is explained by the fact that the condition is congenital, and therefore liable to be equally frequent in any type of eye. The occurrence of crescent in atypical directions in hypermetropic or emmetropic eyes, may result from the occurrence of a similar abnormality of the sclera and choroid in other directions or perhaps occasionally from the stretching of a previously more hypermetropic globe. Coats then accounts for the astigmatism as a fundus astigmatism due to the localized stretching of one portion of the posterior part of the eye. The amblyopia may be due to the inability to fully correct such astigmatism as it may be somewhat irregular. The amblyopia is possibly the result of actual damaging by the stretching of the retinal elements at the fovea. The situation of the crescent is usually downwards and the statistics of Vossius who analyzed 111 cases showed the inferior situation to obtain in 75, or 67 per cent., down and in 8, or 7.2 per cent.; in 9, or 8.1 per cent.; up 5, or 4.5 per cent.; up and out 8, or 7.2 per cent.; down and out 6, or 5.4 per cent. Fuchs' coloboma has been found with typical choroidal coloboma and also with coloboma of the macula. The occurrence of this anomaly in the insane has been noted by Wollenberg who found it present in 1.3 per cent. of insane patients, as against 0.9 per cent. of ordinary eye patients. Also its occurrence in congenital psychoses is said to be increased. Parsons states that in such cases as hysteria, idiocy, epilepsy the percentage is 4.7. As regards the refraction Elschnig who examined 481 eyes found 75 emmetropic, 202 hypermetropic and 204 myopic. He also found temporal crescent in 217, inferior in 25, nasal in 19, superior in 2. He found temporal coloboma in 9, inferior in 14 and superior in 1. Most of these anomalies were in myopic eyes.

Coloboma of the vitreous. This defect is represented by a cleft or groove on the under surface of the vitreous body which, in the more pronounced types, reaches from the papilla to the region of the ciliary body. In other cases it is partial, being only demonstrable in the anterior or posterior part of the vitreous. The depth of the indentation is variable. Usually the cleft is filled with vascular connective tissue.

Hess records a case in which the cleft was filled with a fold of retina. Early observations of this anomaly were made by von Ammon, Arnold, Ecker, Stellwag and Hannover which have been recorded by Manz. The first exact histological investigations of this anomaly were made by Hess, who found the vitreous normal except in one case where there was an increase in the subhyaloid cells. The borders of the cleft were covered with a delicate hyaloid structure. Other cases have been recorded by Bock.

Etiology of colobomata. Much has been written about the genesis of colobomata and much speculation has been indulged in. Various theories have had their day, only to be discarded when some new experiment, observation or discovery had weakened their strongest support. There is much negative knowledge relating to the cause of colobomata and little positive. von Hippel in the Graefe-Saemisch *Handbuch,* 1900, analyzed all the theories, past and present at that time. It cannot be said that any of them are satisfactory. All have their weak points and some have been thoroughly discredited. A recital of all of these theories and the arguments which have been put forward in their support and against them makes interesting reading but is really only of historical interest. No attempt, therefore, will be made here to give these theories in full. Some will be mentioned only incidentally.

The problem appears nearly as far from solution as in the time of Manz. For a time the question seemed solved by Manz's explanation; also for a period by Deutschmann's. The attitude towards all theories has been iconoclastic. In late years little of a constructive nature has been done. Most observers have sought for an explanation which will account for both typical and atypical defects. It may be fair to assume that this is not necessary. To admit that a certain factor is the cause of a defect need not necessarily exclude all other possible factors.

The great preponderance of typical colobomata occurring in the region of the fœtal cleft naturally excites suspicion that the faulty closure of the cleft is the chief cause of colobomata. This was the early view and is still held by a great many with just reason as the explanation of typical defects. It fails, of course, to explain atypical colobomata which caused observers to seek further for an explanation. This has been furnished by those who advocate an inflammatory theory. While the explanation of faulty closure of the cleft has many obstacles to overcome, they are much less insuperable than those of the inflammatory theory. Eminent authorities from von Ammon to von Hippel and including Manz, Bock and Hess have supported the theory of interference with the closure of the fœtal cleft. In explaining colo-

bomata of the iris all theories deserving of consideration presume an obstacle to the ingrowth of the iris from the periphery which takes place at the fourth month. Long before this the fœtal cleft normally should have closed. The occurrence of coloboma of the iris as the only defect arouses curiosity as to why this is so, if the delayed or faulty closure of the cleft is the cause, and why colobomata of the ciliary body and choroid do not also occur. It is necessary to take into consideration the development of the iris. While its stroma and pigment layer are derived from different histological structures the development of these two structures goes forward together, hand in hand. The iris stroma lies immediately behind and adjacent to the thin layer of mesoblast which forms the posterior boundary of the anterior chamber and forms eventually the pupillary membrane. Should then the lower segment of the lens be held forward by persistent mesoblastic tissue which enters through the cleft and which at all points but this has become absorbed, it can be seen that the iris stroma carrying on its posterior surface the anterior lip of the secondary vesicle will meet with an obstacle at this point, but in the rest of its extent will go on to the full development. The amount of obstruction would determine the size of the coloboma and a very small strand of mesoblast would produce a very appreciable defect. It is conceivable that the mesoblast later on could be absorbed, the lens assume its normal position and no evidence remain of the offending tissue. Collins gives an explanation of the development of colobomata of the iris, as follows: "Before the iris is formed in the fœtus there exists between the posterior surface of the cornea and the anterior capsule of the lens, the anterior portion of the fibro-vascular sheath. This receives its blood supply partly from the ciliary arteries and partly from those in the posterior fibro-vascular sheath prolonged along the sides of the lens to join it. The cornea, anterior fibro-vascular sheath and lens lie in close contact with each other. The iris is developed by growing forwards from the margin of the anterior chamber and in doing so has to insinuate itself between the cornea and anterior fibro-vascular sheath on the one side and the lens on the other, pushing the prolongation from the fibro-vascular sheath in front of it. The anterior fibro-vascular sheath subsequently becomes the pupillary membrane of which portions sometimes persist. If we suppose some abnormal adhesions to occur between the cornea, anterior fibro-vascular sheath and lens capsule, or some delay in their separation, at the whole circumference of the future anterior chamber, we can understand how a mechanical obstruction to any growth of the iris forwards would be introduced, resulting in complete absence of

the iris, or irideremia. If the obstruction be confined to a portion only of the anterior chamber, the corresponding portion only of the iris will be prevented from growing forwards and the result will be one or more congenital colobomata." This theory would at one stroke explain both typical and atypical or multiple colobomata of the iris alone, but would not explain the accompanying retino-choroidal colobomata frequently observed and any explanation to be satisfactory, must do that, at least, for the typical colobomata.

Manz (1876) taking into consideration the views expressed by the early writers drew attention to three factors which were deemed essential to the formation of colobomata. These factors, however, explain only the typical defects. The first factor is the defective closure of the fœtal cleft from any cause whatsoever; the second, an abnormal development of the surrounding mesoblast which eventually becomes differentiated into the choroid and sclera; and the third is the giving way before the intra-ocular pressure of the tissue finally closing the cleft which is likened to cicatricial tissue, this tissue becoming ectatic. The failure of closure of the cleft was held to be due to the persistence of hyper-developed or over-vascularized mesoblast or to a retardation in mesoblastic absorption. Coloboma of the iris singly, or of the choroid singly, was held to be due to a local persistence of mesoblast, the remainder being absorbed allowing normal closure. Finally the offending local obstruction was absorbed leaving behind no evidence but the defect. Later investigations raised serious objections to this conception of Manz, principally on account of its failure to explain atypical conditions, and also to the fact that both layers of the secondary optic vesicle, though often very much altered and thinned, are yet frequently found over the colobomatous area. This seemingly refutes the possibility of failure of the fœtal cleft to close being the cause in these cases. Hess formulated a hypothesis which was used to explain aniridia but which could also be applied to coloboma of the iris, ciliary body, zonule of Zinn or the lens. It is to the effect that normally mesoblast of the fibro-vascular sheath passes around the anterior edge of the secondary vesicle to become continuous with the mesoblast which gives origin to the iris and pupillary membrane. In the event of a portion of this tissue being unduly developed or unusually vascularized so that a vessel persists too long, or the strand is unusually resistant, then the mesoblast forming the iris, together with the anterior lip of the secondary optic vesicle, is prevented at this point from growing in and hence an aniridia or coloboma depending on the extent of the strand is the result. As Coats has stated, it is not the mere persistence of this mesoblast which causes the trouble as it normally

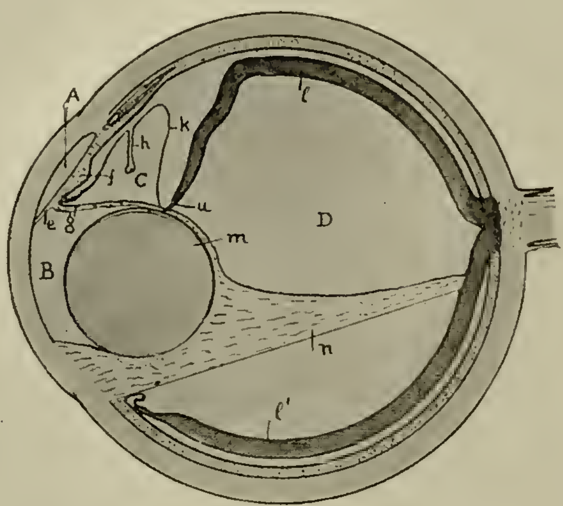
persists till late in fœtal life and in ordinary development yields to the growing iris and follows it inwards over the lens. The theory of Hess takes cognizance of the fact that mesoblast passes forward between the lens and optic vesicle, not alone in the line of the fœtal cleft, but in all directions so that its application, to those rare cases of multiple colobomata of the iris, or to typical choroid coloboma and atypical iris coloboma, or the reverse condition, is very easy. To do so, one must assume a persistence of a strand of mesoblast in two directions, that causing the choroidal coloboma being situated farthest back. A general application of the Hess hypothesis will provide an explanation for many of the congenital defects, such as persistent hyaloid artery, anirida, coloboma of iris, coloboma and ectopia of the lens. In the latter case the mesoblast may persist just long enough to prevent the development of a sector of zonular fibres. Their absence, most commonly below, results in the dislocation of the lens upwards which is the usual position.

Due to the many objections confronting the Manz hypothesis, the theory of fœtal inflammation came into being and claimed Deutschmann for its most ardent champion. He received support from many eminent authorities, including Ginsberg and for a while Van Duyse. At first glance the inflammatory theory would seem to account for a good many of the colobomata, especially the atypical ones and particularly the so-called macular coloboma. As the theory was scrutinized more carefully, it was found to possess difficulties quite as great as that of Manz so that some of its former adherents lost faith and deserted it. In the first place, histological examination failed to reveal any evidence of inflammation where such examination was made on eyes of the fœtus or newborn, though it must be granted that what constitutes early fœtal inflammation is extremely vague, and to say that the remains of fœtal inflammation were not present when we do not know exactly what it is, rather leaves that point open. However, other points more cogent militate against Deutschmann's theory, for instance, the presence of bilateral symmetrical defects. Also the fact that colobomata are usually typical. Why a fœtal inflammation should select the region of the fœtal cleft in the vast majority of cases is hard to understand. In early fœtal development, at which time colobomata have their origin, there is as yet no differentiation of the mesoblast into sclera and choroid, so that one cannot speak of a true "sclerochoroiditis" as being possible. Again the observance of defects in several generations militates against the acceptance of the inflammatory theory for it can not be reckoned with, if heredity be a factor. The appearance of some of the changes in the region of the coloboma

which have been found do not differ much from the appearances of chorio-retinitis occurring in post-natal life, and furthermore these changes have been noticed in other parts of the fundus so that it is safe to infer that such changes are really post-natal. We should bear in mind the great tendency of colobomatous eyes to suffer insidious internal inflammations in later life. Again, the presence of bodily defects, frequently met together with colobomatous eyes, is an indirect proof against the inflammatory theory, among which may be mentioned cleft-palate, hare-lip, facial asymmetry, defects in the bony base of the skull, aplasia of the olfactory nerve, fusion of parts of the brain, malformations of the heart, defects in the hands, arms and toes, atresia ani, microcephalus, etc. Leber drew attention to a possible explanation of how inflammation might exercise an influence in the production of anomalies. It is to the effect that possibly inflammatory processes may influence the whole ocular structure and disappear without leaving a trace, the same as sometimes occurs in post-natal life. Whether anomalies result or not would depend on the developmental stage of the eye which became diseased. The growth of the ocular structures might be so retarded thereby that the cleft fails to close. Such an explanation fails to take account of those instances where the layers of the secondary vesicle are present in the coloboma. Intra-uterine inflammation need not be invoked to explain a hindrance to development. Deleterious substances circulating in the mother's blood might do the same. These substances could be the toxins of disease, including the blighting influence of syphilis and tuberculosis, or chemical poisons like alcohol. The experiments of Pagenstecher along these lines are worthy of note. He was able by feeding naphthalin to animals to produce not only cataracts but colobomata and other defects. His results seem to exclude the influence of heredity as his animals gave birth to normal offspring upon the cessation of the naphthalin feedings. Toxins, whether chemical or other, expend their greatest force on mesoblastic tissues. The rôle of the mesoblast surrounding the optic vesicle has been accorded much attention. If it be hypo- or hyper-developed these changes would be in greatest evidence in the fœtal cleft area which is the scene of the greatest developmental activity. Just what the changes in the mesoblast might be, it is difficult to imagine. However, if we will assume that a disturbance in the surrounding mesoblast, the nature of which is unknown, does occur we have at hand an explanation both of typical and atypical colobomata. The consequences depend on the time when this disturbance takes place. If it be before the closure of the cleft, absence of the layers of the secondary vesicle in the cleft region would be expected.

If after the cleft closure, these structures would be present in the colobomatous area. Coloboma of the choroid need not be accompanied by coloboma of the retina. It has been thought that where the retina is present and the pigment epithelium is absent, the inner layer of the vesicle closed while the outer remained open. This seems hardly possible. The absence of the pigment with presence of the pigment epithelium can be attributed to absence of the choroid as pigment is deposited only after the development of the vessels.

Referring to the early investigations of the causes of coloboma, von Ammon, who dissected the first colobomatous eye, came to the con-

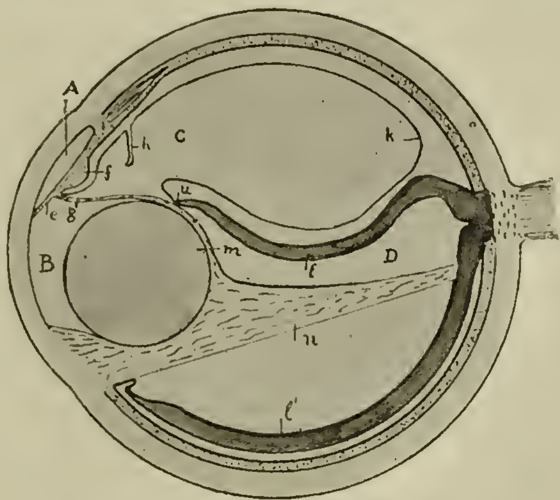


Microphthalmos. (After Coats.)

This figure shows the lens (m) anchored to the mesoblastic strand (n) and displaced downwards and to the temporal side. In its displacement it has carried over a sheet of the inner layer of the optic vesicle (k), so that the aqueous is confined within a loculated space (A, B, C,) bounded anteriorly and at the sides by the external tunics of the eye, posteriorly by the sheet (k), and the lens. (*Ophthalmoscope*. Oct., 1910.)

clusion that the failure of the slit in the choroid to close was the cause of colobomata. Later investigations by Remak, Schoeler, and Kölliker showed that the cleft was not in the choroid, but in the layers of the secondary vesicle and that the choroid and iris normally have no cleft. These observers thought colobomata were the result of the failure of the retinal cleft to close and that the choroid was secondarily involved. Manz then formulated his theory of the factors involved which was accepted for a time. The Manz explanation answered well for typical retino-choroidal colobomata but failed to do so for atypical ones, and another explanation for the latter was necessary. Because of the fact that atypical colobomata were in no way dependent for their formation upon the cleft, the argument was raised that possibly the typical colobomata were likewise independent of the cleft. Ginsberg took the

extreme view that colobomata could only be explained by a theory which excluded the fœtal fissure. In the typical cases it could be assumed that the fœtal cleft closed in part of its extent and remained open partially in which area a coloboma would result. Thus if the anterior part remained open an iris coloboma formed, if the posterior, a choroidal coloboma resulted, and if it failed to close in its whole extent a combined nerve, choroidal and iris coloboma would result. Again, it was thought that possibly the cleft closed and the weak union was later forced open by the intra-ocular pressure. The influence of this pressure is unknown and to apply it as explanatory of



Microphthalmos. (After Coats.)

This figure shows how the sheet (k) has given way, and has become pushed out into the subretinal space, stripping the retina from the choroid, and thrusting it over to the opposite side. A. Anterior chamber. B. Anterior division of the posterior chamber. C. Posterior division of the posterior chamber. D. Vitreous. e. Pupillary membrane. f. Iris. g. Strand running forward from the fibrovascular sheath. h. Ciliary processes. k. Sheet of inner layer of optic vesicle which undergoes distension. l. Retina of the nasal side. l¹. Retina of the temporal side. m. Lens. n. Persistent mesoblastic strand in the vitreous. u. Ora serrata. (*Ophthalmoscope.* Oct., 1910.)

defects in this manner is pure conjecture. The genesis of macular coloboma proved a stumbling block to the Manz theory. The macula lies outwards from the disc, therefore to apply the theory of faulty cleft closure, a rotation of the eye during development had to be assumed. Vossius thought he was able to demonstrate such a complete rotation. The cleft is downwards and slightly inwards, thus the rotation would amount to over 90°. Vossius thought that the vessels entered the cleft in the stalk at the lower and outer part, also that the superior rectus muscle occupied a lateral position and by the rotation of the stalk and globe came finally to be in the nearly median position of later life. Both these suppositions were disproved. Deyl and

Henckel showed that the central vessels did not regularly enter at the lower and outer side of the nerve, the most common position being the lower and inner side. Furthermore, it is definitely proven that the superior rectus always has the same position. Kölliker and Manz thought the fovea was formed at the upper end of the cleft. von Hippel argued that granting this latter contention (which he did not believe) then a rotation according to Vossius's idea would carry the fovea not to the temporal side of the disc but to the nasal side. He further stated that Vossius's arguments disproved themselves as there was no coincidence of time between the supposed rotation of the eye and the shifting of the superior rectus muscle. The rotation theory proved attractive so long as the fovea was assumed to be developed in the fœtal cleft. Chievitz showed that the fovea is a depression in the retina and only develops in the last months of fœtal life and has nothing to do with the cleft. The idea that the cleft extended or could extend above the nerve is disproved. Secondary atrophy, due to ectasia of the inner membranes, can explain the fact that some colobomata extend above the optic nerve and laterally become so extensive that they engulf the macula. The observation of an accessory fœtal cleft was made by von Ammon but was not confirmed microscopically. An undoubted accessory cleft was seen by Van Duyse. Use of such observations has been made to explain atypical colobomata. It would appear that instead of simplifying matters, this would further complicate them. All such observations have been made in animals and it is doubtful if much importance should be accorded them. Deyl thought that a choroidal telangiectasia hindered the growth of the sclera and retina and caused macular colobomata. The later disappearance of such an angioma left behind it a thinned sclera and retina. Lindsay Johnson came to virtually the same conclusion in the cases designated by him, as "extra-papillary" colobomata. von Hippel points out that quite a number of so-called optic nerve colobomata are really circumscribed ectatic retino-choroidal colobomata and would have to be explained in the same way as the "extra-papillary" colobomata. He therefore rejects the telangiectasia theory as incorrect. Parsons agrees that this theory is purely conjectural. Hemorrhages occurring at birth as suggested by Naumoff might be held to explain a number of cases of macular colobomata but not the ectatic ones. Bach assumed that at the time the lens fills the whole secondary vesicle an unequally developed vascular capsule exerted pressure on the retina, while Bock held that at the point of contact of a vitreous vessel with the wall of the ocular cup the layers of the latter could not develop in the regular way. The suppositions are without any basis of fact. The frequent

presence of both layers of the secondary vesicle in the area of the coloboma has been the greatest obstacle in the application of the fœtal cleft theory and led to the supposition that the fault lay in the surrounding mesoblast and not in the cleft. The idea that a coloboma was formed and that later a process of contraction drew the edges of the secondary vesicle together cannot be entertained. Even in the cases where the retina is found missing, we cannot be sure that it was not present at birth, or that the cleft was patulous. Haab drew attention to the fact that the anatomical findings may be very different in the newborn and old individuals. The retina may be present in the entire coloboma in the newborn or embryo and later undergo secondary atrophy as the colobma becomes ectatic in the same manner as it occurs in posterior staphyloma. Bach's theory of coloboma was that an abnormally large lens, or one relatively large, completely filled the vesicle pressed against the retina and prevented the closure of the cleft. It is questionable if this ever happens. von Hippel emphasized the importance of taking into consideration an abnormally persistent and strongly developed mesoblast. He attributed the expansion of the globe to the vitreous fluid secreted which in turn comes from the invaginated mesoblast. If the latter is abnormally dense, an insufficient amount of fluid is secreted and microphthalmus may result, and if none is formed anophthalmia comes about. In the event that the mesoblast proliferates only within the eye and the cleft closes, then microphthalmus without coloboma is produced. von Hippel carried out experiments on rabbits, breeding from a male with typical coloboma of the iris and small colobomata of the iris and lid. Of the offspring, quite a number were affected. Of one hundred and twelve eyes examined, twenty-three had colobomata. Early observations of these showed the lips of the cleft separated by a vascular band of mesoblast which rapidly increased in size. The lips of the cleft were normal. If the amount of vitreous fluid was normal, the vesicle was of normal size and the retina spread out without folding. If the reverse was true, the retina folded and overlapped the edges. The pigment epithelium stopped at the border. These changes occur chiefly in the posterior part of the cleft. Should the folding of the retina become pronounced, it may be pushed out of the cleft into a space which will later form an orbital cyst.

Coloboma of the nerve. Where there is a loss of nerve substance at its lower part, with absence of the central vessels, it is most probable that the optic nerve groove did not close. The nerve groove may close, however, without enclosing the central vessels. Excavations lying wholly within the nerve may be due to an incomplete filling up of the tube after the groove margins have come together. This filling up

results normally from an ingrowing of nerve fibres and a proliferation of the cells of the eye stalk. One or both of these may be missing. A further supposition is that ectasia of a normally formed nerve might result secondarily from some want of resistance of its tissues.

Coloboma of the ciliary body has only been observed in a downward direction. Those cases in which the ciliary processes are only diminished in size and displaced, have been explained as a result of a secondary ectasia, in the region of the accompanying choroidal coloboma with cicatricial shrinkage. This cannot always be so as ectasia is not present in every case (Pause).

Iris coloboma. The theories of Manz, Collins and Hess have been given (*vide supra*). The iris is developed from epidermal and mesodermal structures. Failure of the cleft to close in the former does not account for the absence of the latter for while a defect in the lip of the cup would prevent the choroid growing forward at that point, we cannot assume that the stroma part of the iris grows out of the choroid. The idea that the cleft remained open and later closed in its posterior part is untenable. It is far easier to explain isolated coloboma of the choroid than of the iris, as the latter is late in developing. Further, we know the cleft did not remain open in some cases as the retina is intact in the area of the accompanying choroidal defect. Manz, basing his opinion on the examination of an atypical coloboma, in which the iris at various points showed a divergence of the radial fibres and the choroid a thinning of its outer layers, thought the deformed iris could be explained as a deficient outgrowth of the atrophied choroid. To refute this, it is but necessary to repeat that the iris is not an outgrowth of the choroid. Mannhardt thought that some cases could be explained on the theory that the iris is pulled back by cystoid changes behind in the sclera, and is therefore not a real defect, but a distortion. This assumption is highly hypothetical. Two other possibilities can be considered which can prevent the growing out of the iris, especially of the edge of the vesicle. Depending upon the extent and location of the obstruction, will be the size and position of the resulting defect. 1. The adhesion of the vascular lens capsule with the surface of the lens. 2. Atypical development of the mesoderm, joining the interior of the vesicle with the surrounding mesoderm. The influence of the first possibility is questionable. The occurrence of deposits on the anterior lens capsule has been cited as evidence in favor of this view. The findings of Schubert who states that pigment spots are found in 33 per cent. of all cases examined for the same tends to weaken this contention. The second possibility is founded on fact and is really the basis of Hess's theory previously given. Worthy of mention here is

the classical case of Hess where a strand which hindered the development of the iris was demonstrable in the developed eye. It is conceivable that such a strand could be later absorbed and nothing remain visible but the coloboma.

Rumschewitsch thought that if the two layers of the iris failed to coalesce at any point a rarification of the tissues occurred producing a coloboma. Von Hippel dismisses this as incomprehensible. Supporting the inflammatory theory of iris colobomata are the occasional presence of adhesions, absence of the regular markings and atrophic formations. A perfectly regular form of a coloboma due to inflammatory causes is difficult of comprehension.

Coloboma of the lens. Many explanations have been offered for this anomaly. Von Hippel states that it is doubtful if everything which is described as a lens coloboma represents a congenital developmental defect of the lens. At the site of the defect, lens substance might formerly have been present, become disintegrated and later absorbed. These spaces lie behind the equator whereas colobomata are defects of the edge. In many cases the lens capsule is missing at the site of the coloboma. This may, however, depend on the tug of the zonule. Rogman assumed that the defect represented merely a displacement of lens substance. Kämpffer explains these cases in much the same manner, attributing the defect to insufficiency of the zonule and designates them as pseudo-colobomata. Becker thought the absence of pull of the zonule, where a sector of that structure was missing, was the cause of the defect. Heyl explained the coloboma as due to insufficient nourishment by a portion of the vascular lens capsule. Hess took the opposite view, that a persistence of a branch of the vascular capsule might mechanically hinder the growth of the lens. Colobomata with a straight line margin have been thought to have originally been notches, converted into a straight line by the pull of the zonule (Kämpffer). Bock attributed the defect to an incomplete closure of the cleft, due to a persistence of a mesodermal projection. Bach thought an abnormally large lens prevented the ingrowth of the mesoderm which, by the mechanical pressure it exerted, led to a circumscribed destruction of lens substance.

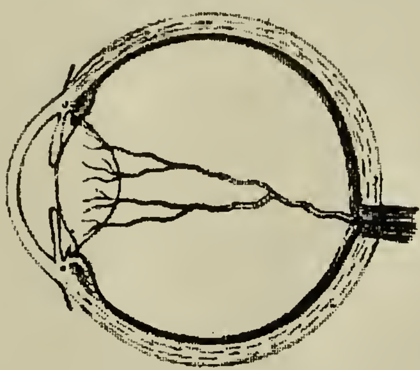
Persistent hyaloid artery. About the only congenital anomaly of the vitreous, other than coloboma, to which attention has been directed and which is observed clinically is the persistence of remains of the hyaloid artery, a vessel, or vessels as the case may be, normal in fœtal life up to the 7th month, at which time its disappearance should occur. Since the development of the vitreous, which formerly was supposed to take its origin from the mesoblast, is now known to take place from

the anterior part of the retina, it leaves the invaginating mesoblast entering through the cleft but one important function, that of carrying vascularized tissue to developing parts. As the cleft extends into the stalk of the vesicle the vessel destined to form the central artery of the optic nerve gains entrance to the nerve through this cleft whose walls later begin to fold under laterally and are finally closed. From behind an arterial twig passes into the eye through the vitreous after having traversed the fœtal groove in the stalk. It gives off a few branches to be of but temporary duration for the supply of the posterior part of the vitreous and is then continued onwards through the center of the

Persistent Hyaloid Artery. (After Hess.)

vitreous to the posterior lens surface, dividing dichotomously into a number of branches and spreading out on the lens surface to form the posterior vascular sheath. It is surrounded by a fibrous sheath and has an additional membranous tubular sheath in which it lies free, known as the canal of Cloquet. Its course is straight or sinuous depending upon the time at which it is observed, being straight in the later stages of development, sinuous in the earlier when the vitreous is shallow. As the vessel leaves the stalk it is generally single though two or even more vessels have been observed. After forming a stellate network in the posterior lens surface branches bend over the edge of the lens and enter the vascular net-work in the anterior surface of the lens. In this manner a complete vascular envelope, the membrana capsulopupillaris of the lens is formed. The hyaloid artery has no accompanying vein, the blood being carried off partly by the circumlental plexus of veins and thence to the cilio-choroidal system, and partly by the peripheral vitreous plexus and thence finally joins the central retinal system. After the optic stalk has completed its folding under and encloses the vessel lying in its groove, the vessel is then designated as the arteria centralis retinæ. From it vessels grow out to supply the retina, but have no connection with the temporary vessels of the vitreous above mentioned. At the beginning of the sixth month of gestation the fœtal arteries begin to be obliterated. The hyaloid artery becomes empty and white just behind the lens, its caliber becomes

smaller and finally it separates usually from the lens or at some point in its anterior portion. The remnant attached to the lens gradually disappears and the stellate vascular body on the posterior lens surface rapidly thins out and is absorbed. The posterior end of the hyaloid artery shrivels up and disappears leaving behind, for a short period yet, a conical process of the tissue which surrounded it, as it sprang from the central artery. This cone-shaped process then thins and finally disappears. The process of absorption and disappearance of the fœtal vessels usually progresses equally in the two eyes although exceptions to this are very common. At any period during absorption the process may be stopped thus producing the large clinical variety of hyaloid remains so frequently observed. The condition is usually unilateral. Quite a number of bilateral cases, however, are reported.



Persistent Hyaloid Artery terminating Dichotomously. (Tangemann.)

Formerly hyaloid remains were considered quite a curiosity but the number of cases revealed through careful fundus examinations of recent years have shown it to be not a very rare condition.

In 1856 Heinrich Müller reported the frequent occurrence in the eye of the ox of a short process projecting from the optic disc into the vitreous. A similar observation was made in the human eye in which an anatomical investigation was being conducted. The prediction was made by Müller that soon an observation of this anomaly with the ophthalmoscope would follow in the living human eye. The prediction was verified in the next year when Zehender (1857) detected the anomaly ophthalmoscopically, being the first one to do so. However Zehender did not report his case at once, which gave Saemisch in 1863 the opportunity of claiming that honor by the report he made that year. After these, scattering cases were reported by various observers when in 1890 De Beck prepared a monograph on the subject covering and giving in detail the cases collected up to that date, nearly two hundred in number. Since then the number of cases has increased very much. Different writers have divided the cases into groups more or

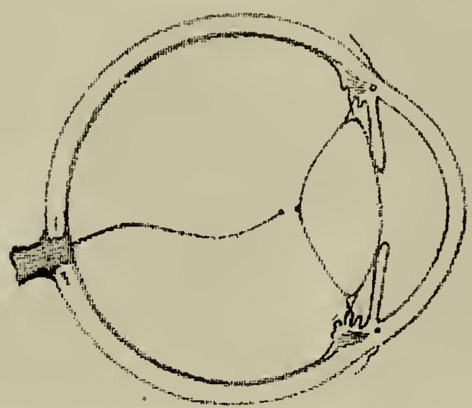
less arbitrarily, depending on the amount and situation of the fœtal remains. De Beck by making fine distinctions found his cases fell into one or the other of a dozen groups. He gave these twelve divisions as follows. (A) Shreds of tissue on the optic disc. (B) Membranes on the disc. (C) Cystic remains on the disc. (D) Masses of connective tissue on the disc. (E) Rudimentary strand attached to the disc. (F) Strand attached to the disc, and a vestige also at the posterior surface of the lens. (G) Strand passing from the disc to the lens. (H) Similar strand containing blood. (I) Strand attached to the lens alone. (J) Posterior capsular cataract. (K) Striæ on the posterior lens capsule. (L) Persistent canal (without any remnant of the vessel).

In most cases it is the posterior fragment which is observed. Less frequently the whole artery is seen attached at both ends and more rarely still it contains blood. At times new-formed, adventitious vessels are seen running along the surface of the hyaloid remains and should not be mistaken for hyaloid vessels containing blood. As to the origin of such vessels there is considerable difference of opinion. It was first thought that the condition represented a persistent canal of Cloquet instead of the artery itself (Manz, de Wecker, Galezowski, Holmes, Bayer, Oeller). The canal of Cloquet is always persistent, that is, it is always normally present as shown again recently by the researches of Bribach, but under normal conditions it is perfectly transparent and invisible, hence the preceding conception is objected to by different writers, and some other factor is thought to be present which results in its being opaque and visible. Where a strand is connected at both the optic nerve and posterior lens surface its solution or breaking in the middle may take place leaving both ends attached (Remick, Loring, Lawrence, Hasbrouck). Due to the elongation of the eye in a developing myopia the same occurrence has been observed (Unterharnscheidt). In the condition most commonly met with clinically there is seen with the ophthalmoscope a bluish-white, oftentimes a brownish, fine, delicate cord threshing around in the vitreous as the eye is moved from side to side, which is attached to the disc and less frequently to the posterior lens surface. At times, without good illumination and a careful search, the cord is liable to be overlooked due to its delicacy and steel color which makes it hard to detect. Where the remnant is but a tag on the posterior lens surface it constitutes the so-called posterior polar cataract. The least marked findings which presumably are hyaloid remains are the shreds of tissue on the disc occasionally observed, and which have aroused some discussion as to their genuineness. As observed, not rarely, they are irregular clumps or

bands of connective tissue upon the disc. They are glistening white and almost transparent so that where they cover a vessel it is distinctly seen running beneath them. Less frequently they are opaque and either completely hide the vessels or allow but a faint view of them. Schmidt-Rimpler, and later Schaumberg, described similar cases but designated them as instances of double contoured nerve fibers upon the disc. Berger in 1882 described three cases and regarded them as mild, diffuse neuro-retinitis with exudation. To both of these conclusions De Beck took exception and satisfactorily proved they were hyaloid remains. At times instead of a shred of tissue there is present a distinct membrane of glistening white color covering more or less of the area of the disc and usually encroaching somewhat on the adjacent retina. Such membranes are generally of a thickness sufficient to completely hide the vessels. It has been assumed that such membranes are due to a flattening down of the base of Cloquet's canal at its termination on the disc, the rest of the hyaloid system having been completely absorbed. In other instances the hyaloid tissue instead of being disposed as a membrane occurs in irregular clumps or masses of connective tissue. A small number of very interesting cases have been observed where the remains of the hyaloid artery were seen in the shape of a cystic expansion upon the disc. These are usually of a steel-blue color and are round or oval. Their translucent appearance is indicative of fluid contents. These little cysts vary somewhat in size and position, some being flask-or knob-shaped with a neck or pedicle-like formation.

Referring again to the common variety where a narrow strand passes through the vitreous, it arises usually in a clearly defined manner from the disc or still more rarely from a branch outside the disc. It passes forward for a variable distance terminating in an end which floats free in the vitreous. The termination may be single, multiple, in a knob-like swelling or in fine fibrillæ. A few cases of this ordinary type are further distinguished by the presence, in addition, of a distinct remnant at the posterior pole of the lens indicating the former anterior attachment of the artery. This attachment is not always central, lying at times to one side, eccentric. Next in frequency are the cases where the artery is attached at both ends. This was designated by De Beck the type form of this anomaly of which all other forms are but variations. Of this type was the case of Saemisch referred to above as the first one put on record where the condition was observed by the ophthalmoscope. Rarely observed are those instances where the artery is attached at both ends and carries blood. In some cases the vessel and its branches carrying blood are in virtually the same condition as

they were at the height of fœtal activity (Gardiner, Eversbusch, Tangemann). Where in similar cases the lens is perfectly clear, the manner of the escape of the blood is of interest. It is presumably by way of exceedingly fine capillaries. There is a fairly large group of cases where a vessel containing blood emerging from the disc, passes for a variable distance into the vitreous and then turns upon itself and passes back again to the disc or retina. It may disappear in the disc or be distributed to the retina. Objection is raised to including these vessels under the head of persistent hyaloid vessels, but it is held that they should be considered as anomalous branches of the central artery of the retina. Not many cases are found where the only remains

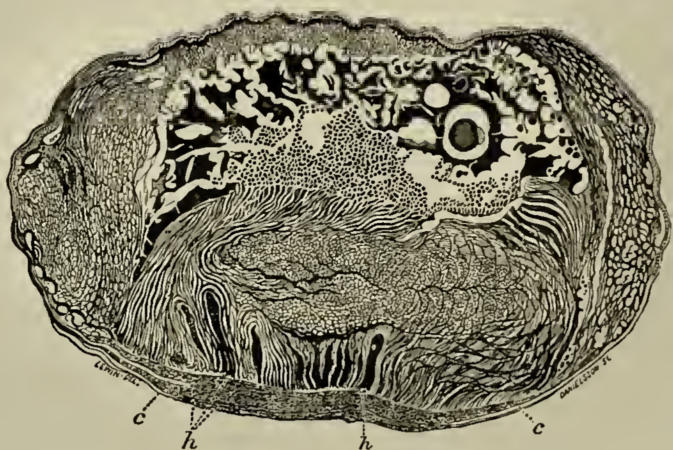


Persistent Hyaloid Artery with the Posterior Portion floating Free in the Vitreous. The anterior and smaller part is attached to the posterior aspect of the lens. (After Loring.)

of the hyaloid artery is a filament attached to the posterior pole of the lens, the disc being free and the filament extending backwards and terminating in a free end moving in the vitreous. Nearly all of congenital posterior cataracts are simply remains of the hyaloid artery and are on the posterior capsule and not beneath it; the latter condition constituting true posterior polar cataract. The hyaloid remains being upon the posterior surface of the posterior capsule are found as rounded or irregular masses. Their position is at times eccentric. They appear brown or grayish. They are properly termed posterior capsular cataract. The opacity may vary from a mere speck to a fairly good-sized mass which at times assumes a conical shape with the apex pointing backwards. The least marked examples are fairly common but the average observer is often in the dark as to whether he is dealing with a genuine posterior capsular cataract or not. Occasionally these posterior opacities have faint striæ radiating from them. In a very limited number of cases these striæ of a white or gray appearance represent in their ramifications over the posterior lenticular surface, the only vestige of the previous fœtal vascular system. One of the

most interesting of the varieties of persistent fœtal remains is the membranous lining of the canal of Cloquet. This canal is a tubular channel commencing at the optic disc and extending through the vitreous towards the posterior pole of the lens near which it terminates. It is about the size or a trifle larger than the disc, being about 1½ mm. in diameter. After the disappearance of the hyaloid artery the walls of the canal are invisible, due to their transparency. In the adult it is said to contain vitreous. Abnormal development of its walls makes it visible. Its existence is denied by some authorities (Wolfrum). The membranous tube usually terminates at either extremity in a funnel-shaped expansion considerably longer than the mean diameter of the tube. In some cases this funnel-shaped expansion covers the greater part of the disc, in other instances the trumpet-shaped end is anterior, the sheath fading away towards the disc and there ending in a thin, pointed extremity attached to the disc. In observing such a case ophthalmoscopically it gives the impression as if one were looking into the large end of a trumpet. Occasionally it is seen that the sheath apparently divides into two or more branches, which divisions are presumably the true coverings of the original branches of the hyaloid artery, as it is not known that Cloquet's canal itself divides in such a manner. De Beek made the statement based on his observations that the persistence of this canal is generally found in both eyes, whereas in the ordinary forms of persistent artery the remnant is uniocular in more than five-sixths of the cases. As met with clinically an eye containing hyaloid remains usually appears normal externally. Often it is by chance in the course of a routine examination that the anomaly is detected. Thus in many of the cases vision is found normal. In others vision is affected to a more or less degree depending on the amount of hyaloid remains present and the presence of concomitant defects. The patient may be cognizant of something floating across his field of vision or may not notice it until his attention is drawn to it. Thinning of the strand at times takes place after birth so that a strand may break through in the middle and the patient in this way become aware of it. Reference is here again made to the instance in Unterharnscheidt's case where this happened due to stretching in a progressive myopia. Galezowski observed in a child in whom well-marked persistent hyaloid remains existed, that at the end of three years the remnant had dwindled to some small floating shreds attached to the disc. Secondary changes occur, however, not very frequently. The cases in which a floating strand is continually whipping about in the vitreous, producing a fluidity of that body, would seem to predispose to secondary changes, but these do not by any means follow.

Among the complications described as occurring with hyaloid remains, especially with manifest canal of Cloquet, are disseminated choroiditis, pigmentary degeneration of the retina and posterior capsular cataract. The explanation of the patches resembling choroiditis (Rockliffe, Randall, Dimmer, Lang, Brailey, Maisch and others), are varied and they probably are caused by different conditions. Some are taken to be instances of a congenital choroiditis (Bayer, Holmes) while others are regarded as of hemorrhagic origin, the hemorrhage having occurred intra-partum. A phenomenon noticed, where the persistent artery contains blood, is that pressure on the eyeball produces pulsation. Gardiner described spontaneous "rhythmic move-



Persistent Posterior Sheath of Lens. (Treacher Collins, *R. L. O. H.*, XIII.)

The lens is cataractous. c, c. Ends of posterior capsule, the space being occupied by vascular connective tissue. h, h. Hemorrhages in lens substance.

ments." In many of the cases in which vision is greatly reduced there exist concomitant defects responsible in great part for it and the following have been reported: (1) coloboma of the iris, (2) coloboma of the choroid, (3) macular coloboma, (4) coloboma of the nerve head, (5) cystic coloboma, (6) aniridia, (7) persistent pupillary membrane, (8) congenital cataract, (9) ectopia lentis, (10) coloboma of lens, (11) anterior lenticonus, (12) posterior lenticonus, (13) atypical vitreous, (14) microphthalmia, (15) buphthalmia, (16) epibulbar dermoids. These may occur as the single accompaniment of the hyaloid remnant or several defects may be present. Stephenson reports a case showing a beautiful capsulo-pupillary membrane with a central plaque, a persistent hyaloid artery and atypical development of the vitreous and strabismus. Strabismus is not an infrequent accompanying condition. Some of the intraocular changes occurring with persistent hyaloid artery are of doubtful congenital origin, but are attributed to secondary inflammatory changes. This

may well be, as observation frequently is not made until adolescence or adult life is reached. Eversbusch doubted the genuineness of a large proportion of the cases described as persistent hyaloid remains but looked upon them as pathological products. He believed that exudation into the vitreous following by choice the line of least resistence spreads along the open canal of Cloquet and gives rise to the appearances of persistent remains of the hyaloid artery. Tags of tissue and membranes upon the disc are likewise open to question. In support of this view is the occurrence of choroiditis in many cases. The supposedly congenital origin of the choroiditis is a matter of doubt as it may be post-natal. In support of the genuineness of the fœtal vascular remains is the occurrence of numerous instances of concomitant congenital defects as above noted. In De Beck's monograph the cases collected showed a sum total of nearly one hundred congenital anomalies other than the persistent hyaloid arteries out of a total of 174 individuals presenting 199 examples of a persistence of some portion of the fœtal hyaloid system. Opportunity for microscopical examination of these eyes, especially the slighter forms of persistent hyaloid artery, seldom arise. Examination has been made in a few cases where the remnants gave rise to a suspicion of pseudoglioma. Manz and Nettleship have recorded such instances. Thorough microscopical investigation of persistent hyaloid artery have been made by Treacher Collins and by Parsons.

Vitreous vessels. Persistent vessels in the vitreous other than the hyaloid are described. Vessels emerging from the disc and passing forwards into the vitreous and which then turn back again to the disc or retina have given rise to some confusion in properly classifying hyaloid remains. The vessels are considered as distinct from hyaloid vessels. Bunches of fine vessels arising from retinal vessels near the disc, and found in the periphery of the vitreous, have been described by Hirschberg. It is doubtful if they should be considered as congenital. Similar structures are observed frequently in syphilitic cases and as a retinitis proliferans following vitreous hemorrhages. Parsons makes the important point that the peripheral fœtal vessels are all veins and disappear early whereas the presence of a hyaloid vein is unknown. Crampton reported a case of a young man O. D. V. 6/6, O. S. V. 6/60, due to a high refractive error. Examination of the right eye showed a slightly pulsating loop of vessels which was seen close to the posterior surface of the lens, and taking its origin from the center of the disc where it appeared to spring from the lower nasal vein in a close spiral. The fundus was otherwise normal and the vitreous clear. The long, twisted loop was free from superfluous

connective tissue and seemed patulous throughout. Hansell described a connective tissue formation in the vitreous probably arising from the optic nerve and accompanied by vessels. The origin of the vessels of the vascular portion of the mass could not be determined. They were of good size, fixed, and supposedly arose from the optic nerve. He believed it to be a "congenital growth in the vitreous springing from the optic nerve sheath and vascularized by fine branches from the vessels of the disc."

Tortuosity of retinal vessels. This anomaly which is at times marked is not of much interest except in those cases where it is unilateral and where its occurrence might prove misleading in deciding as to its significance. It occurs unilaterally and bilaterally and either concerns the veins alone, or both veins and arteries. It is generally associated with hypermetropia. (Benson, Nettleship, Mackenzie). Its association with angioid conditions of the face and body has also been noticed (Horrocks, Dodd, Hartridge).

The arrangement of the vessels on the disc is very variable. In some instances the center of the disc is free of all bloodvessels, the vessels entering and emerging at the margin, in which cases the center is quite pale (Lawford). The veins at times all unite forming one vein which is found in a looped condition lying partly on the disc and partly on the retina. Two veins may be joined together by a short branch, or a branch of the veins may form a loop and collect other veins (Werner). An artery and vein are commonly found coiled around each other, barber-pole fashion, just before they enter the disc. Another frequent occurrence is where the artery forms a loop projecting into the vitreous a short distance and then returns to the disc. Instead of the vessels dividing dichotomously, at the first division after leaving the disc, the vein, especially, may divide in a trident manner. These conditions are of no significance.

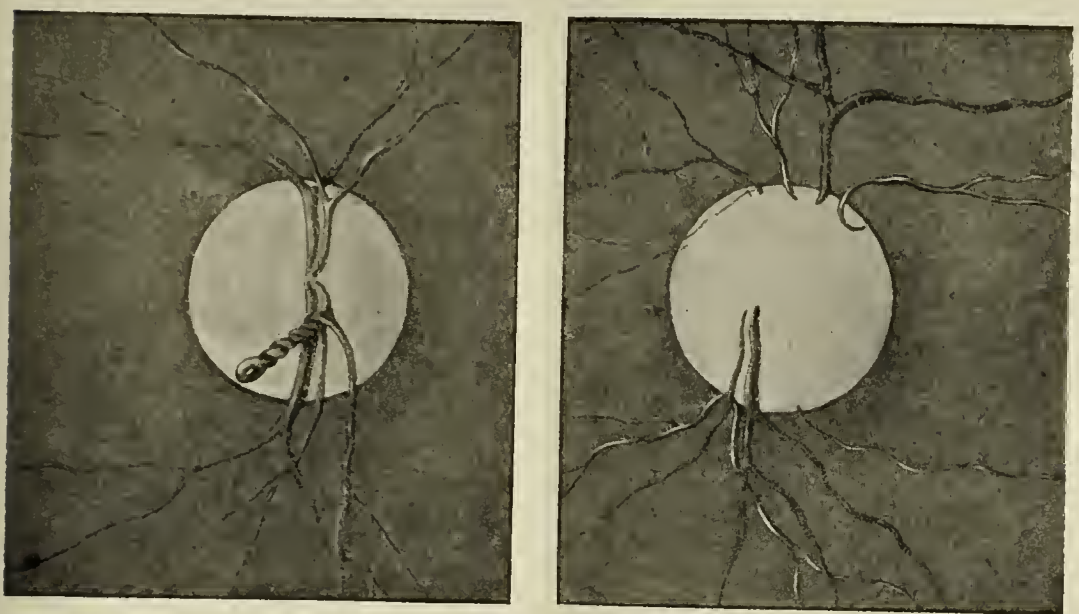
Bifurcation of veins. This condition has been seen in several instances. The branching takes place at or near the disc. The branches may communicate with other veins. Bahn reported an anomalous condition of the inferior temporal vein of one eye. The vein was three times the normal size and at the edge of the disc divided into two separate and distinct branches, in which condition they entered the nerve.

Arterio-venous anastomosis is very rare. Where this occurs there is no varicose condition of the vein. The anomaly has been observed by Marcus Gunn.

Absence of the retinal vessels is exceedingly rare. Cases have been described by Graefe and Retze. An instance was reported in the

American literature, the reference to which could not be found by the writer.

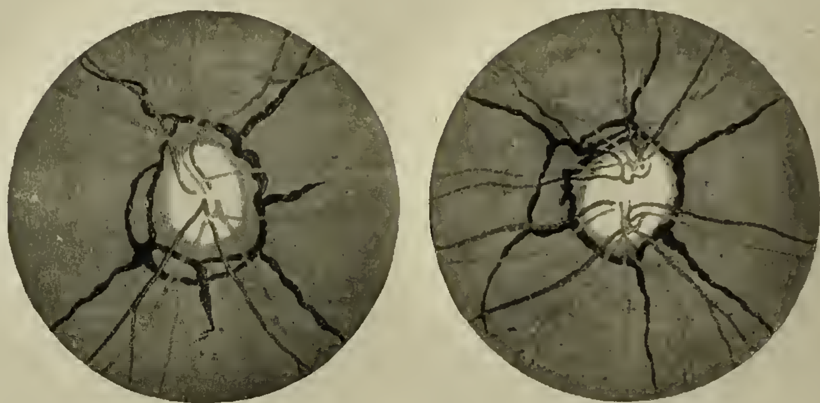
Cilio-retinal vessels. The occurrence of these vessels is relatively common. The origin and distribution is suggested by their name. Cilio-retinal arteries are much more frequently found than veins, although, as Jackson suggests, a systematic search might show them more common than we have supposed. Cilio-retinal arteries were discovered first by Donders and H. Müller and demonstrated anatomically by Nettleship. They are found in about 20 per cent. of



Vascular Anomalies of the Optic Papilla. (After Kipp.)

all eyes examined. Jackson in a series of 500 patients (1,000 eyes) found cilio-retinal vessels in 19.1 per cent. of the cases. In addition to these were 40 eyes in which the vessels were so completely isolated from the branches of the retinal artery as to give rise to the idea that they came from the ciliary arteries. Including these, his percentage would be 23. These vessels always emerge from the temporal side of the disc and pass to the macular region. They occur with equal frequency in the two eyes. The usual direction of the vessel is firstly towards the center of the disc, it then makes a sharp bend and passes outwards towards the macula. Close examination shows that they can be traced from the extreme disc-margin, or can be seen starting in the choroid at times branching from a large choroidal vessel entirely beyond the edge of the disc (Jackson). Unless the vessel makes the characteristic sharp bend one is unable to say that it is not a branch of the central artery before it comes to the surface. After coming to

the surface of the disc the artery may so change its direction as to pass off of the disc considerably above or below its point of emergence. The condition is generally unilateral. As a rule there is but a single vessel though in a few cases two are present. Their position may or may not be symmetrical with regard to the horizontal diameter. A few instances have been observed where the vessel was not a choroidal branch but a scleral one. It has been thought that possibly cilio-retinal arteries represent a survival or reversion to the type of retinal arterial distribution common to the lower vertebrates, as described by Lindsay Johnson and Nettleship. In Jackson's series of 191 eyes,



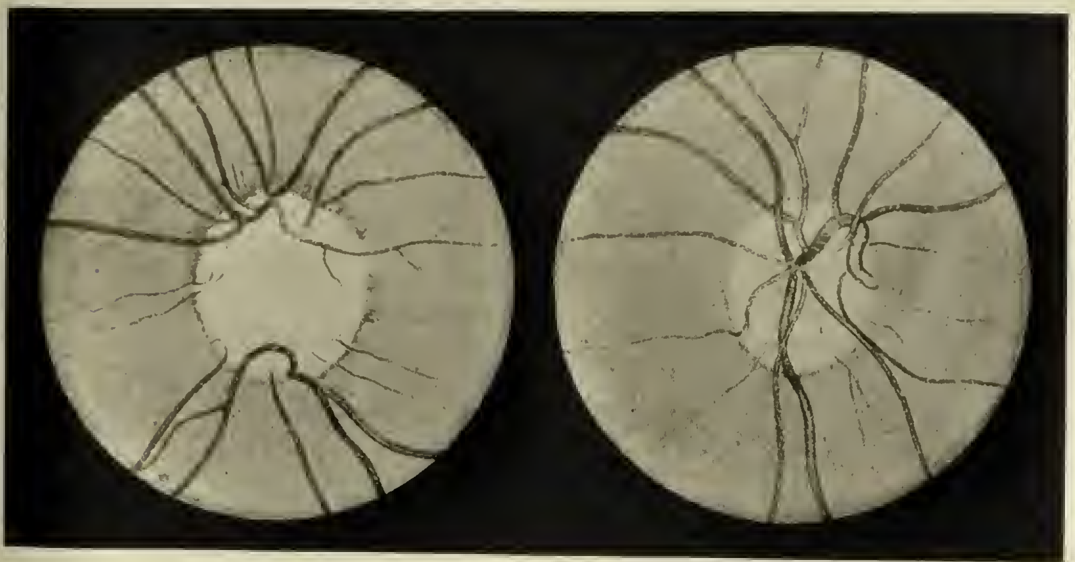
Congenital Anomaly of the Optic Discs. (After Coppez.) (*Ophthalmoscope.* Aug., 1908.)

the vessels in 188 passed from the outer side of the disc and terminated in the region of the macula. He concludes that this almost constant macular distribution is not accidental, but is not inclined to decide that it is a provision of nature against possible accidents to the central retinal artery. Cilio-retinal arteries have no anastomoses, they are therefore terminal arteries. Visible pulsation is more frequent in cilio-retinal arteries than in branches of the central artery of the same size. Czermak divided cilio-retinal arteries into four groups: (a) those ending at the choroidal border of the disc, the usual form; (b) the vessel disappears into the sclera; (c) the vessel arises from a sclero-choroidal vessel; and (d) the artery arises from a choroidal vessel. Leber believed that cilio-retinal vessels were branches of the circle of Zinn and Elschnig supported this view.

Cilio-retinal veins are very much rarer than arteries, due, as held by Leber, to the almost complete absence of veins in the circle of Zinn. In Jackson's series there occurred two cases; in one a vein of medium size apparently emerged from the choroid through the retina a disc's diameter external to the disc. At its point of emergence it received two small veins. In the other case the vein arose

between two branches of the central artery and its branches crossed the arterial twigs. Parsons states that when these are observed, they are probably of new formation following inflammation.

Choroido-vaginal veins. These are also called "posterior vortex veins." They are found in eyes highly myopic as large venous trunks which resemble very much vortex veins but disappear in the neighborhood of the disc. In practically all of the cases the eyes are myopic, the exception being that of Schoute's. According to Coats they are uncommon but not extremely rare. However, they are easily overlooked and misinterpreted. Schoute gave a full account of the condi-



Abnormal Retinal Vessels. (Lawford, *T. O. S. U. K.*, XV.)
Left eye, all the vessels emerging from the margin of the disc.

Right eye, with large optico-ciliary vein.

tion and in 1903 had collected 13 cases of his own. They are extremely large, dead-looking vessels, without lustre or reflex and occupy a position behind the retinal vessels and collect blood from a large area of the fundus. Their general direction is downwards and outwards and they are seen on but one side of the disc. The fact that they are veins and not arteries has received ample proof. Confusion of this condition with visible choroidal vessels has occurred but is easily avoided by noticing the oftentimes enormous size of these vessels which have even been mistaken for hemorrhages. If followed to the disc it will be seen that the large vessel disappears under its edge. The pathological knowledge concerning these vessels is very limited. That they are congenital is granted. Elschnig believed the veins represent a congenital enlargement of the normal minute anastomoses between the central vessels on the nerve head and the choroidal

vessels. He thought that choroido-vaginal veins differed from them only in degree. It is not known what becomes of these veins or into what vessels the blood collected by them is poured. It has been thought by some that this anomaly represents simply a misplaced vortex vein. The association with myopia is not understood. Van Geuns pointed out that these vessels probably are the same as those which give rise to optico-ciliary veins.

The best explanation of choroidal vaginal veins is, according to Coats, that of Van Geuns, which is that these veins arise from an unusual development of the normal anastomoses around the nerve entrance. The retinal and choroidal circulations of the eye are entirely independent as shown by Leber and others. There are three exceptions to this rule in the occurrence, viz., of the cilio-retinal artery, the choroido-vaginal vein and the optico-ciliary vessel. There are anastomoses between twigs of the choroidal and central vessels around the nerve entrance. Leber holds that these take place in three directions. 1, Backward to the pial sheath. 2, Straight inwards to the region of the lamina cribrosa. 3, Forward to the papilla. These have nothing to do with the circle of Zinn which is made up entirely of arteries. Parsons contends that the difference between choroido-vaginal and optico-ciliary veins is not one merely of degree, as Van Geuns has declared, but that a different anastomosis is involved. Parsons also takes exception to the term posterior vortex veins as it implies that they are abnormally placed vortex veins, which he considers as without foundation, both on practical and theoretical grounds, and that the name choroido-vaginal is correct as it describes their anatomical course.

The association of these veins with high myopia is so constant that it is thought some connection must exist between them, and Coats infers that it is one of cause and effect brought about in the following manner—the myopic eye yields chiefly in the posterior half, the vortex veins are left in their normal position. This interferes with venous return. All this is greatest on the temporal side, as here the tunics give way most. As a result of the obstruction the blood seeks an outlet wherever it can find one, and this is found in the anastomotic channels already present at the nerve entrance.

Optico-ciliary vessels. This is a very rare congenital anomaly. Shoemaker states that at the time of his report (1909), only ten or twelve cases had been recorded, though doubtless many more had been seen. Of ten cases reported two were arteries and eight were veins, and in Braunne's case the anomaly was bilateral. Not much is known in regard to optico-ciliary vessels. They occur in certain dis-

ease conditions such as papillitis and glaucoma, and in such instances are of course acquired. The congenital vessels run from the central or papillary vessels to the disc margin and disappear under the retina into the choroid. Benson showed the first case in 1883 and described as "an unusual course taken by a branch of the central artery of the disc." The subject has been written on by Elschnig and Niels Höeg. Bloch divides the cases into two classes according to the direction of the flow of blood. 1. The blood flows from the choroid towards the central vein, the condition being analogous to the choroido-vaginal vein.

Optico-Cilliary Vein. (After Shoemaker.)

To this class belong the congenital cases. 2, The blood flows from the central vein into the nerve sheath or choroid; a modified cilio-retinal vein. To this class belong the acquired cases. Shoemaker concluded that in his case it represented an errant choroidal vein and in case the eye were highly myopic, or the retinal pigment absent, it would be a so-called choroido-vaginal vein, which instead of ending at the sheath of the nerve, would pass on to the central vein of the retina. He suggests that as the vein has no connection with the ciliary vein, it would be better named optico-choroidal vein.

Aplasia of retina and optic nerve. Absence of the optic nerve and retina are noted in anencephaly (Manz, V. Wahl, Mayou) in cyclopia (Van Duyse) and occasionally in some cases of hydrocephalus. The nerve fibres and the ganglion cells are entirely absent, whereas the outer layers of the retina may be nearly normal. Absence of the nerve is noted also in anophthalmia and microphthalmus. Meissner

reports the microscopical findings in a case of coloboma of the choroid and retina with aplasia of the optic nerve as of interest because the eye was of almost normal size, portions of the secondary optic vesicle fully developed, the fœtal cleft closed and the anterior ocular segment normal. There was complete absence of the optic nerve, rudimentary development of the choroid, retina, and pigment epithelium in the region of the fœtal cleft (coloboma). In the entire retina there were no functionally active ganglion cells, nerve fibres or vessels. Besides this, there was an atypical coloboma of the retina, and pigment epithelium situated in the ciliary body. The cornea was vascularized and the iris poorly developed. Von Hippel noticed as a rare condition aplasia of the optic nerve with microphthalmus. In his case a benign tumor sprang from the glia. He thought it was identical with the case of Helfreich's which prior to Von Hippel's was the only recorded case of the coincident occurrence of microphthalmus and glioma. There was double-sided hare-lip and cleft-palate.

The cause of aplasia of the nerve and retina has been the subject of a variety of explanations. By some it is looked upon as secondary to the widespread cerebral defects generally present, the highest type of which is anencephaly and this in turn being attributed to hydrocephalus. Pressure of the amnion has been invoked as a cause (Perls, Dareste). Overcurvature of the embryonic axis preventing closure of the medullary canal, is the view of Lebedeff. Petren sought to explain the condition as a "system defect," to a defect in the neurones of a particular order. The anatomical findings fit in with this theory as the outer layers are often in fair condition, the ganglion cells and the nerve fibres being the structures absent. On the other hand, it is satisfactorily explainable as a secondary degeneration.

Krauss (*Bericht d. ophth. Gesellsch.*, 1913, p. 380) has reported and described a rare fundus condition reproduced here as a colored plate. It was found in a twelve-year-old girl who presented no congenital anomalies, nor was there reason to believe that hereditary influences played any part in the production of the defect. The right eye was normal but the left one was divergent 15°, very amblyopic, nystagmic, with vision reduced to hand movements. In the latter affected eye there also was an absolute scotoma below and to the temporal side. The pupillary reaction, to direct light, was sluggish, although the other reflexes were normal. The media in this eye were clear and the periphery and macular region normal. The whitish mass, which is seen to extend in and up from papilla, is reproduced in the colored picture. It is probably made up of connective tissue. It extends out into the vitreous, though parts of it lie in and upon the

retina. The principal areolar strand shows a rounded thickening and presents at its free end glove-like processes that end abruptly in the vitreous. This principal part is covered by fine, veil-like processes not easy to distinguish. In the neighborhood of the optic nerve entrance, also, there may be seen at least one connective tissue strand that forms a direct connection with the retinal tissue. The optic disc appears to be rather pale but its temporal margin is sharply differentiated from the surrounding retina. The point of entrance of the optic nerve is abnormally distant from its usual situation and lies behind the areolar strand whose connection with the retina has just been referred to. It will be noticed that there are some chorioidal anomalies to be seen, especially in the distribution of pigment.

Crateriform Hole in the Optic Disc. (After Stephenson.)

It is difficult to do more than guess at the histologic disturbances that gave rise to this picture. There seems to be no evidence of an intrauterine inflammation, so that one must be satisfied with the statement that the chief points to be noticed are the excessive growth or developmental persistence of glia or connective tissue in the vitreous and retina, and the displacement of the point of entrance of the central vessels.

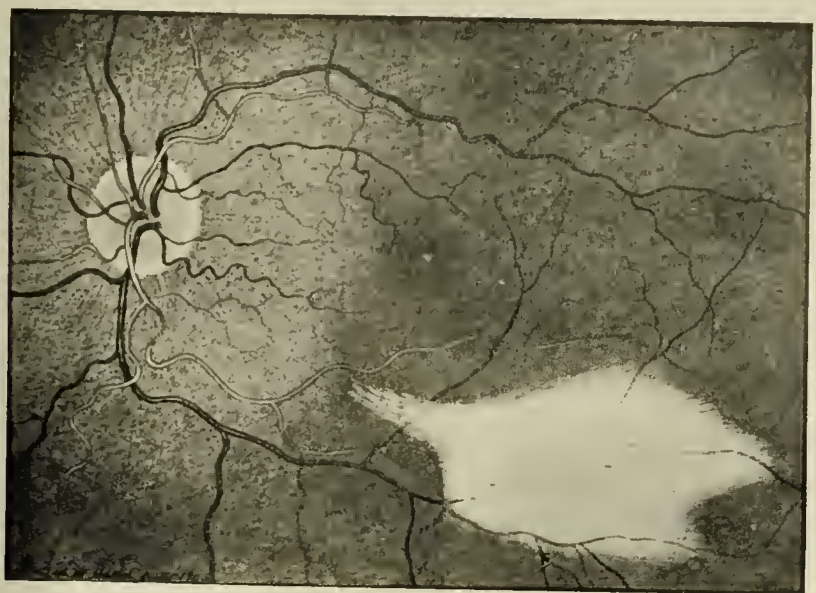
Hole in the disc. Crater-like hole in the disc is an exceedingly rare anomaly. James (1913) was able to find but twenty-one cases in the available literature. Only three cases had been reported in London, by Marcus Gunn, 1886; Frost, Stephenson, 1896, and Stephen-

son in 1909. Another case in London was, however, reported by Carr in 1909. Reis (Bonn) reported that he had seen the anomaly five times in ten years among 55,000 patients. That so little is known of so typical and characteristic an anomaly was a matter of surprise to Reis. James evidently overlooked some cases, as Reis in addition to his own five has tabulated 15 other published cases. Of these twenty cases, thirteen were females, six males, and in one the sex was unknown. Usually but one eye is affected but in a case of Strood's both were involved. Several holes may be present in the same disc (Reis, Wiethe). The position of the hole is usually in the outer half of the disc which in that position may show a localized extension (Thompson and Ballantyne, Reis). They are said never to occur above the horizontal line. The depth varies and is difficult to accurately estimate. In Carr's case the depth seemed to be the equivalent of 3 D. and in Lichtenstein's to 24 D. Reis and Stephenson described the hole as being covered anteriorly by a fine tenuous pellicle, difficult to see. A small vessel is sometimes seen in the hole skirting its edge or at the bottom of the pit. The hole has a dark color sometimes olive-green which is due to the shadow cast from its edges (Stephenson). The vision with correction in most of the cases has been normal or nearly normal. Macular changes have been noticed in several cases (Reis, James) in which event the vision is reduced. In Reis' case the macula showed a hole surrounded by a stellate figure of delicate radiating streaks. A central scotoma was present; at times a paracentral scotoma is found and has been ascribed to the defect in the disc. Reis states that the appearance is not so much that of a hole opening anteriorly as of a cystic defect in the mass of nerve tissue just behind the surface of the papilla. Most writers seem to think that the anomaly is an example of incomplete coloboma at the optic disc. Coats reported the pathological findings in two cases of hole in the disc and believes the condition arises "by the evagination of a portion of the secondary optic vesicle into the nerve, or more probably by the abnormal differentiation of part of the neural division of the vesicle into pigment epithelium and retinal elements." Coats does not think the anomaly has any connection with the fœtal cleft.

Large disc. Hack of Würzburg reported a case in which the optic disc was considerably larger than normal. It contained in the center a white, star-shaped body with a silky lustre and was surrounded by a yellowish, pigmented halo. There was no cup. The retinal vessels were arranged in a radial manner at the margin of the disc. Out-

lining each vessel on both sides and accompanying them for a distance into the fundus, was a broad white stripe.

Medullated nerve fibers. Normally as the optic nerve passes into the lamina cribrosa it becomes diminished in calibre due to the loss of the medullary sheaths of its nerve fibres and to the disappearance of the coarse intraneural septa. Medullation does not reach the lamina cribrosa before birth, therefore medullation of fibers in the retina occurs early in post-natal life; hence Fuchs states that this anomaly which is called congenital, we know certainly now cannot be congenital. In the rabbit a band of medullated fibers is normal.



Medullated Nerve-Fibres. (After Lawson.)
Near the macula and apart from the optic papilla.

When seen in the human they form brilliant white spots usually adjoining the edge of the disc and splitting at its periphery into white fibers giving a paint-brush or flame-like appearance. Generally these areas are at the upper or lower borders of the disc, but may surround it completely. The medullated fibers lie rarely within the papilla itself or are found far from the disc in the peripheral retina, clear, transparent retina intervening. The retinal vessels in places are covered by the medullated fibers. The vision is frequently reduced. Virchow made the first microscopical examination in the pre-ophthalmoscopic days. Schweigger made the first anatomical confirmation of the ophthalmoscopic picture. As regards frequency Mayerweg saw seven cases in 1,727 clinic patients. Von Hippel's ratio was 1 to 1,000; Manz 1 in 3,250; Wollenberg 40 in 6,131. Kölliker

found in the records of the Zürich clinic from 1872 to 1883 only 58 cases. Of these 87 per cent. were uniocular, 13 per cent. binocular. Deformities of the skull were present in 13 per cent. Strabismus in 48 per cent.; myopia in 48 per cent.; hyperopia in 31 per cent.; emmetropia in 20 per cent. The fibers ran upwards or downwards, and never invaded the macula though often enclosing it. Stephenson described a patch of medullated nerve fibers five disc diameters from the papilla. J. F. Shoemaker reported two unusually situated patches of fibers, in one the spot was in the upper temporal quadrant of the fundus about four disc diameters from the optic nerve. In the other they were in the lower nasal quadrant two to three disc diameters from the nerve, the intervening retina being entirely normal. Schreiber found opaque fibers in a series of dogs where the lamina cribrosa was well developed which disproves, he thinks, the hypothesis that the normal lamina presents a mechanical obstacle to the development of medullary sheaths. Von Hippel concluded that this is not a congenital anomaly in a true sense, but that only the predisposition to its development is congenital. This is supported by the findings of Kölliker mentioned above, of congenital deviations from the normal, and of concomitant anomalies, such as persistent hyaloid artery, cavernous angioma, and an unusual form of conus described by Mayerweg. Mayerweg concludes that the development of medullated nerve fibers in the retina occurs by preference in the eyes of persons having already congenital defects, and that therefore it is not an accidentally acquired condition, but is dependent on congenitally predisposing factors.

Congenital detachment of the retina. A report of two cases occurring in brothers is made by Fernandez. It was noticed early that they were blind. A diagnosis of glioma had been made in one case. Examination under atropia revealed the true nature of the condition. The parents were young and healthy. Fernandez quotes Locktewr, Cruchandeau, Sidler, Huguenin, Hirschberg and Antonelli as being inclined to assume a luetic etiology for cases of congenital detachment of the retina.

Lachrymal apparatus. The anomalous lachrymal conditions met with are atresia of the puncta lachrymalia, absence of the puncta, supernumerary puncta and canaliculi, slit-like or gutter depression of the lower canaliculi, displaced canaliculi, absence of the lachrymal bone, absence of the lachrymal gland, dislocation of the lachrymal gland, absence of the lachrymal sac and nasal duct, fistulæ and dacryocystitis congenita. In the human at about the sixth week of fœtal life the first evidence of the lachrymal channel is seen (Ryder)

in the form of the lachrymo-nasal groove. This reaches from the eye to the outer border of the nasal opening corresponding in the adult to a line from the inner canthus to the outer posterior margin of the nostril just within the ala nasi, where it joins the cheek. (Tooke.) This is parallel in the adult with the nasal duct. The lachrymo-nasal groove is an involution of the ectoderm. A thickening on the under side of the epidermis along this groove constitutes later the nasal duct. Except at each end this thickened ridge separates as a solid cord, acquires a lumen and becomes thereby a canal of ectodermal origin. The upper end of the originally solid cord expands and divides into two small branches, the canaliculi, ending as the puncta. Kuesel reported a number of cases of congenital slit formation in the upper wall of one or both canaliculi, the rest of the tract being normal. He thinks this supports Halben's theory that the canaliculi are formed by late prolifieration from the lid margin and not by an extension from the epithelium of the tear sac. In the slit formations there is therefore simply an arrest of development with failure of the slits to become bridged over. Congenital stricture of the duct is a result of incomplete canalization of the primitive fœtal lachrymal cord. Tooke states that should the involution of ectoderm be incomplete at any point besides the natural end of the lumen constituting the punctum, that this accessory opening must be accepted as a congenital fistula, or, as he prefers to call it, "a fœtal cleft." Writers on the subject of development of the canaliculi are not agreed. Born and Legal say that the upper canaliculus is a continuation of the primary chain of epithelial cells and the lower develops by supplementary growth of the upper part of the naso-lachrymal duct. Kölliker and Ewetsky think the canaliculi develop by division of the upper end of the naso-lachrymal duct. Cosmetattos, Stanculeanu and Matys think that the lower canaliculus is a continuation of the primary naso-lachrymal duct, and that the upper develops later by a secondary offshoot from the upper part of the original naso-lachrymal duct. A doubling of the upper canaliculi is explained by a double offshoot from the upper naso-lachrymal duct, which grow in the same direction and later form two canaliculi. Double lower puncta can be explained by a division of the continuation of the naso-lachrymal duct which goes to form the lower canaliculus. Maud Carvill states that should the secondary growth of epithelial cells which is freed from the epiblast, and grows upward to form the canaliculus, and downward to assist in the formation of the naso-lachrymal duct, fail to grow downwards and grow only outwards to the border of the lid, we would have a punctum formed opening into a blind canal.

Such cases have been reported. The upper end of the secondary growth of cells might divide and form two puncta with their individual canaliculi, which would join before reaching the naso-lachrymal duct; or the supernumerary punctum might open directly into the normal canaliculus depending upon the point where the division took place. Carvill says that many of the supernumerary puncta and canaliculi which have been reported illustrate the former condition, whereas the latter condition corresponds to the case of congenital fistula of the upper canaliculus reported by her.

Tooke reported two cases of so-called doubling of the puncta lachrymalia, but concludes that they should not be considered as puncta, as we understand them morphologically, but as clefts due to a non-development of the fœtal lachrymo-nasal groove. Congenital anomalies of the lachrymal apparatus are relatively rare. Moore in over 100,000 eye-patients found one of absence of the punctum, and one with three puncta.

Supernumerary puncta are generally found in the lower lid but have been found in the upper. Sometimes a normal canaliculus has two puncta or each punctum has a separate canaliculus which may empty directly into the lachrymal sac, or the two may unite before reaching the sac. Supernumerary puncta of the lower lid have been reported by Graefe, Galezowski, Weber, Zehender, Manz, Steffan, Baer, Schirmer, Talko, Homer, Fitzgerald, Streatfeild, Foltz and Nance. Supernumerary puncta of the upper lid are reported by Bochdalek, Van Boyer, Zehender and Vossius. In the Bochdalek case there were three puncta in the upper lid.

Fistulæ. Manz doubted the existence of congenital fistulæ but admitted its possibility. De Wecker mentioned a number of cases from the writings of other observers. Cases have since been recorded by Agnew, Hartridge, Casey Wood, Dunn (unilateral), Roy, Barnes, Tyson, Loehlein, and others. Loehlein examined three cases of congenital fistulæ of the lachrymal sac of non-inflammatory origin, and found the sections to correspond almost exactly with those of normal canaliculi. From his findings, coupled with the modern researches concerning proliferation in the fœtal tear passages, he concluded that congenital fistulæ of the sac are not the result of an arrest of development but of an unusual growth of an epithelial sprout from the tear passages, and are thus similar to the normal and the supernumerary canaliculi. In Tyson's case the fistula was noticed virtually at birth, there being no doubt about its being congenital. It was unilateral. Agnew's case was noted when the child was two years old. All the other observations were made in persons from 10 to 40 years of age,

so that doubt arises as to their being congenital. Doubtless many are the result of a dacryocystitis either congenital or post-natal. The cases where Loehlein made anatomical investigations were proved by his findings to be of undoubted congenital origin. The condition is usually bilateral. Dunn's and Tyson's cases were unilateral. Makenzie, Steinheim and Terlinck have reported true lachrymal gland fistulæ with the opening upon the skin of the upper lid. In Terlinck's case the opening was surrounded by fine hairs and was situated at the extreme temporal side of the upper lid 8 mm. from its margin. The fistulæ ran about 6 mm. into the orbit. The escape of lachrymal secretion was small but increased greatly when the child cried or when the lid was everted. The orbital and palpebral glands were separate. The orbital gland emptied through the fistula. The fistula was excised, healing took place quickly but a new fistula soon appeared at the outer canthus. A hitherto unobserved faulty development of the sac is reported by Wernicke in which the right fossa for the lachrymal sac was replaced by a deep opening as large as the tip of the little finger. Canaliculi were not present. From the opening a large canal led into the nose in the direction of the normal lachrymal passage. The patient could breathe through this opening when his mouth and nose were closed. Wernicke ascribed the malformation to a failure of the lachrymal groove to close.

Atresia of the punctum has been reported but twice (Zehender, Lafite-Dupont). Two observations were made by Zehender of atresia of one or more puncta. The opening is closed by an epithelial membrane, while the canaliculi are normal and patent. Simple incision of the membranous obstruction, with the passage of a probe, is all that is necessary for the cure of such cases. Traumatic or inflammatory causes must be excluded in making a diagnosis of congenital atresia.

Absence of the puncta lachrymalia is very rare. Moore found one instance. Magnus reported two and in each of his cases the defect was in the lower punctum right and left. In Emmert's case all four puncta were absent. Some doubt exists as to the true congenital origin in these cases as one patient was 22 years old and the other 6. The canaliculi were described as being absent. In these cases all trace of the punctum and its tubercle is lacking. Failure of the puncta to develop would be due to a non-canalization of the epithelial cord from which the canaliculi are formed, and Parsons does not think absence of the canaliculi is sufficiently substantiated. Von Hippel also says it is difficult to prove the absence of the canaliculus. Another case of bilateral absence of the lower puncta is reported by Luedde. Double dacryocystitis existed as long as the patient could remember. Appar-

ent cure was brought about by dacryocysto-rhinostomy. All the reported cases show an involvement of the lower puncta and in only one case were the upper also involved. In no case were the upper alone involved.

Absence of the lachrymal bone has been observed by Barfurth and Zabel.

Absence of the lachrymal gland was recorded in a case of cryptophthalmia examined by Van Duyse. The lachrymal gland is not absolutely essential to lubrication of the conjunctival sac and could therefore be absent without jeopardizing the integrity of the cornea. The absence of tears might be due to suppression of secretion or absence of the gland, therefore absence of lachrymation is no proof of absence of the gland. Absence of the gland has been stated to be the rule in anophthalmia but Parsons says this is not the case.

Displacement of the puncta is described by Augieras in a patient whose palpebral apertures were narrowed by an excess of skin at the internal canthus. The puncta were displaced outwards being situated only 2 mm. internally to a tangent to the inner side of the cornea. The canaliculi were double the normal length and instead of following the margins of the lids and uniting immediately internally to their junction, were continued separately for a distance into the redundant skin.

Congenital dislocation of the lachrymal gland is a rare anomaly. The protected position of the gland makes dislocation very uncommon, though a number of traumatic cases have been met with. Snell has reported one case of non-traumatic dislocation, and one congenital dislocation of both glands. Noyes, Mauthner and Brière have also reported cases. Jones described a unilateral congenital dislocation in a girl of 10. The gland was found beneath the upper eyelid and close to the outer canthus of the left eye. It could be easily reduced into position and retained there by the finger.

Absence of the lachrymal sac and nasal duct are very rarely observed. Beyer alone noted the failure of the sac to develop. A number of instances of absence of the nasal duct are recorded (Otto, Travers). Two cases of absence of the duct with absence of one side of the nose, which was replaced by a snout-like projection, are recorded by Selenkoff and Landow. On the opposite side of the face in these cases the nose and ducts were normal. Landow explained the condition as being due to amniotic pressure. A remarkable anomaly was observed by Kraske and Van Duyse and Rutten, where a canal existed which connected the sac with a hare-lip. The anomaly occurred in individuals with patent facial cleft and lid colobomata.

Purtscher recorded the case of a child of four with epiphora, ectropion and coloboma of the iris. At the position of the lower punctum was a long and slightly-gaping cleft. The region of the tear sac was slightly swollen and on pressing it some thick mucus appeared in the conjunctival sac, and at the same time a large drop of the same secretion issued from a very fine fistula situated underneath the nostril in the skin of the upper lip.

Congenital dacryocystitis. Jackson, in dealing with the subject of delayed development of the lachrymo-nasal duct, states that lachrymal obstruction showing immediately after birth, or as soon as the secretion of tears has begun, is due to the delayed development of the nasal end of the lachrymal duct, unless disease in the nose or parts adjoining in the lachrymal passages offers a different explanation. He referred to autopsies made on new-born children by Vlocovich and Rochon-Duvigneaud which brought to light cases where the orifice connecting the duct with the nose had not opened. As no tears are formed in the first weeks of life no demand is made upon the passages so that in many instances nothing is noticed until tears begin to be secreted. Where conjunctival symptoms are present the canaliculi are open. Extraneous material reaches the interior of the sac, infection occurs and dacryocystitis develops. The usual symptoms of that condition are then present, viz., distention of the sac, regurgitation on pressure, inflammation about the sac, and lachrymal conjunctivitis. Mayou concludes from his observations relative to this trouble that, (1) throughout development the lower end of the duct is small and remains so at birth being partially occluded by the pressure of the inferior turbinate bone. (2) That at birth the sac and duct are filled with epithelial débris. (3) That at birth the duct is either not patent or not fully so. It is a clinical fact that one passage of a probe will clear the duct and prevent the formation of an abscess. The condition is quite common. Formerly few observations were made while of late years many have been reported. Peters saw forty cases in eight years, Hirsch reported five cases. Mayou treated eight cases in the new-born. Ollendorf described seven cases in infants which he regarded as being of congenital origin. The affliction is sometimes bilateral (Cassimatis). Usually it is unilateral. Peters found the trouble on the left side in six cases, and on the right side in only one. Hirsch found the ratio between left and right side affections, 3 to 2. Ollendorf is of the opinion that the dacryocystitis almost always precedes the conjunctivitis. The cases of Fejer presented on the third day of life, or later, pus with an almost unaltered conjunctiva and no gonococci. In many cases gonorrhœa or any other vaginal

infection can be absolutely excluded. Hirsch found the pneumococcus in the pus in three cases. The organisms found in the purulent contents of the abscesses by Mayou were the gonococcus, staphylococcus, pneumococcus, and Morax-Axenfeld bacillus. In no instance was a pure culture obtained. One of the peculiarities of a mucocele in the baby is the large size it may attain without showing much external evidence. This is accounted for by Donald Gunn as due to dilatation of the duct. Mayou however showed that it was due to the peculiar anatomical conditions in the newly-born. Cassimatis, commenting on the speedy cure of his case by the injection of a warm physiological serum, concluded also that the sac and duct were of abnormally large size.

Melanosis oculi. Cornea. Congenital pigmentation of the cornea is uncommon, especially in the deeper layers. Cases have been described by Krukenberg, Stock, Thompson and Ballantyne, Kraemer, Tweedie and Holloway. In some of the reported cases there is a note of purulent conjunctivitis within a few days after birth. (Van Duyse, Wintersteiner, Gesang, Polte.) Parsons states that these cases are probably due to intra-uterine inflammation with transference of uveal pigment to the cornea. In two cases described by Krukenberg and the others by Stock, Thompson and Ballantyne, Kraemer, six histories in all, and the three cases of Holloway's, it was found every time that a pigmented area was present in both eyes, central in position and occupying the deeper layer of the cornea. In acquired and some forms of congenital pigmentation, the spots are superficial. In all the cases the granules were brown in color but of varying shades, reddish-brown, chocolate-colored and golden-brown (Holloway). The spots are best seen by oblique illumination. The lesions in all the cases were approximately symmetrical. The shape of the lesion is oval or of spindle form. In Kraemer's case it was a horizontal spindle. The size of the spots varies; 2½ x 1 mm. (Holloway) 4⅓ x 3½ mm. (Krukenberg's). The color of the irides is of interest, being about equally divided between brown and various shades of gray. In virtually all of the cases the refraction is myopic. The vision while reduced is not out of proportion to the refractive error. Females are more frequently affected than males. Thompson and Ballantyne decided the condition is congenital for the following reasons: (1) The lesions are symmetrical. (2) The dots are the same size. (3) The dots are interstitial. (4) Evidences of inflammation are missing. (5) The eyes are myopic.

The cause of the anomaly is not definitely known. Krukenberg thought that the similarity in color between the pigmented area and

the iris stroma indicated some connection between the lesion and the anterior uveal tract, but could not explain the vertical position of the spindle. Stock agreed with Krukenberg. Thompson and Ballantyne offered no explanation but thought the underlying cause a definite and constant one. Wüstefeld thought the separation of the pupillary membrane had some possible remote connection. Von Hippel thought these cases were due to a keratitis, either intrauterine or post-natal. He points out the possibility of mistaking the results of a post-natal "internal ulcer," for a congenital defect, especially if another anomaly be present, as in his case reported in 1901. The probability of a syphilitic influence is to be considered since Schweigger has indicated the possibility of an anterior synechia developing in interstitial keratitis without perforation of the cornea. Probably the best dissertation on the subject in English is by Holloway to which the reader is referred for the text and complete bibliography.

Pigmentation of the sclera in minor degree is not infrequent in man. In animals it is relatively common. It may be found around the anterior perforating ciliary vessels. Coover presented a case of a white woman of 60 who had "always had a dark eye." She had pronounced negroid sclerotics. In the right eye two-thirds of the iris were deeply pigmented. The fundus was unusually pigmented and vision only 2/200. The left eye had a vision of 6/9 and a visual field contracted for green and blue, less so for white. Tension and nerve head were normal though "rainbow circles" suggested glaucoma.

Under this subject it may be well to describe blue sclerotics. This condition, while not a pigmentary change yet gives to the eyeball a blue appearance. Blue sclerotics as a congenital disease were first described by von Ammon in 1841. He described it as a peculiar whitish-blue coloration of the sclera which appeared almost transparent. He saw the condition in congenital hydrophthalmos and in patients with congenital heart disease in which cases the sclera was dark blue, due partly to its peculiar thinness and partly to a venous engorgement, and a large amount of pigment in the eye. From von Ammon's time up to ten years ago the condition received scant notice when Buchanan examined a case anatomically and found the cornea and sclera very thin, the cornea 3/5, the sclera 1/3 the normal thickness. Bowman's membrane was completely absent. Hay (1907) described a localized thinning of the sclera in a child the subject of many other anomalies. In 1908 Peters called attention to the hereditary transmission of blue sclerotics in four generations coming to his attention. A typical embryotoxon was present in four of his cases. Roll in 1908 reported a case of "sky blue sclerotics" to the Ophthal-

mological Society of the United Kingdom. Stephenson in 1910 traced the anomaly through four generations, the condition affecting twenty-one out of the thirty-two members. In his cases the complexion was fair and the inheritance was through the females. Two of the cases showed an embryotoxon. Harman later added another generation to Stephenson's collection, making a total of thirty-one affected out of fifty-five members traced. Rolleston (1911) observed a case in a child the offspring of syphilitic parents. The mother had blue sclerotics and an embryotoxon, as did also the child. The mother's sister and grandmother had blue sclerotics. The mother did not contract syphilis, however, until one year before the baby's birth. The interesting features of his case were a history of blue sclerotics in three generations, an extra-genital luetic infection of the mother and the occurrence of a spontaneous fracture of the humerus in the child. Rolleston mentions a paper by Eddowes entitled *"Dark Sclerotics and Fragilitas Ossium,"* where are described some cases occurring in families in which the two conditions were associated. Eddowes had not suspected the possible existence of inherited syphilis in his cases. Following Rolleston there appeared a paper by Adair-Dighton reporting blue sclerotics in four generations. In almost all of the patients there was a history of frequent fractures. One patient showed embryotoxon. There is no note in Adair-Dighton's cases of syphilis. Unfortunately these cases could not be followed up to ascertain if there existed a relation between blue sclerotics and osteoporosis, or if the former is dependent on the latter or both due to a common factor. The condition is characterized by a thinning of the sclerotics allowing the uveal pigment to show through, or else the sclera is uncommonly transparent. What brings about the thinning or transparency we do not know. Possibly syphilis directly or indirectly is the real underlying cause. The subject is just now arousing interest and subsequent observations and anatomical investigations will no doubt throw much light on its genesis and pathology. See also **Blue Sclerotics.**

Pigmentation of the conjunctiva is frequently seen in dark races, occurring as small patches of pigment at the limbus. When seen in the white races it is always suggestive of malignant disease. It is a question if the condition is ever really one of congenital pigmentation.

Congenital pigmentation of the retina has been observed in a few instances. Parsons examined such a condition microscopically, the pigment spots consisted of aggregations of very densely pigmented retinal epithelial cells.

Pigmentation of the disc. This condition seems to have been

observed more frequently in later years than previously, quite a number of cases appearing in the literature. Liebreich's atlas 1870 mentions the condition. Dyckmeester stated that up to 1900 only six cases of congenital pigmentation of the disc had been published. These were reported by Liebreich, V. Foerster, Hirschberg, Schleich, Hilbert and Wiethe. The disc is generally grayish black; in Coats' case it was pure black. The pigmented areas may take up a sixth to a third of the disc. It may be distributed at the periphery, the center being free. Again it may extend out onto the retina irregularly or in the shape of a tongue. The disc may be surrounded by a ring of black pigment due to a heaping of the retinal pigment at its margin. In Pick's case there was a radial striation. Fejer's patient showed a dense layer of pigment covering the optic disc, there was high myopia (13 D.), and some pathological changes in the shape of areas of choroidal atrophy and some spacing of the pigment. Dyckmeester's case had hyperopia (3 D.), the right fundus showed a temporal conus and just within this the disc contained an elliptical area dark-blue in color with a slight greenish tinge. Parallactic displacement showed the area depressed below the surrounding surface. In Coats' case the pigmented area was decidedly swollen to the extent of about 2 D. The spot outside the disc was apparently covered by retina appearing as a faint shimmering veil. Close to the disc in an upward nasal direction there was a delicate translucent connective tissue film which covered, without concealing, the vessels. This latter led Coats to conclude that the disc pigmentation was congenital as against the two other possible diagnoses, sarcoma and pathological pigmentation. Many instances of pigmentation of the disc have been reported following hemorrhage, with or without optic atrophy, and these must be carefully excluded in arriving at a diagnosis of congenital pigmentation. The explanation of the anomaly is not clear. Fejer thought it to be due to an incomplete retrogression of the excessively developed pigment which occurs in the embryonic optic nerve.

Heterochromia iridis. Heterochromia iridis, as its name implies, constitutes a condition of difference in color of the two irides. Usually one eye is brown and the other blue or gray. The whole iris is not always affected, only a sector may be involved, the lighter area being blue or gray, the remainder brown. When this condition is present in both eyes the term bilateral heterochromia or dicorus is applied. Heterochromia iridis occurs in two forms, one being an anomaly and the other a symptom of a definite disease. To the latter Butler has given the name heterochromic cyclitis. Hutchinson

first drew attention to the subject in 1869, describing three patients who had a blue and a brown eye. One of these had anisocoria; the pupil of the blue eye was but half the size of the brown eye. Not till 1889 was the subject revived. Sym and Gunn published cases in that year. Sym noticed that usually the color of one eye corresponded to the mother's and the other to the father's eye. It was also noticed that the lighter eye was frequently affected with choroiditis, cataract and opacities in the vitreous. In Gunn's case the blue eye developed cataract. Most of the recorded cases were brunettes; all of Malgot's nine cases, the one of Gunn's and most of Sym's were brunettes. The hair and eye brows are generally normal. Lutz (1910) went deeply into the subject and described it fully. Heterochromia iridis is occasionally seen in cats which possess white hair and is therefore related to albinism. In the latter condition the cats are always deaf, whereas in heterochromia iridis they are not deaf. Congenital heterochromia iridis is a teratological condition and not a disease. As Butler says, "It is not possible to make an absolute classification between the uncomplicated congenital form and the complicated form, for some of the simple congenital variety, although not complicated with cyclitis, do manifest abnormalities. Thus the blue eye has often a smaller pupil than the brown one and the blue iris may show iridodonesis." Galezowski recorded seven cases of heterochromia of the irides, in three of which there was no cataract. In several there was inequality of the pupils and palpebral fissures, and even in the prominence of the globes. In three cases there were signs of paralysis of the sympathetic on the depigmented side. The condition is a rare one. Lutz found that it constituted only 0.2 per cent. of the cases at the Zürich clinic. Butler saw only two cases, one simple and one complicated, in six thousand patients, a percentage of 0.03. The proportion of men to women affected is as sixty to forty (Fuchs). Nearly all observers have sought for evidence of hereditary transmission but failed to find it. In a majority of the cases heterochromy was noticed at birth (Butler). Nearly all children have blue eyes at birth, due to the iris stroma containing little pigment, the posterior pigment only being present and complete. If there be but slight increase in stromal pigment, the eyes remain blue. If pigment is laid down faster in one iris than the other, a difference in coloration is noticeable. If partial excess or partial arrest of pigmentation occurs, a light or dark patch in a sector of the iris is seen. Most writers from Hutchinson to Lutz have noticed the tendency of the lighter eye to disease. As an exception to the rule that the lighter eye is the one which always suffers disease, is the case of Butler

where the reverse was true. Beaumont thinks disease of the lighter eye should be expected, as the iridic pigment has a protective purpose and its attenuation may lessen this protection, but he does not think we can generalize and say that blue eyes in non-heterochromic persons are more prone to disease than darker ones. Cataract is probably the commonest complication. Glaucoma is occasionally seen. Sym saw it in three of his ten patients. Lutz saw two cases and Butler one. A discussion of heterochromic cyclitis, while intensely interesting, does not concern us here as it is a disease process and affects eyes which usually were not heterochromic at birth. Those cases showing heterochromia at or shortly after birth should be considered congenital, whether or not they later develop cataract, glaucoma or cyclitis.

Albinism. The eye is probably the richest pigmented organ of the body, hence when pigment is lacking as a whole, the eye is conspicuous owing to its loss of coloring matter. Not only the eye, but the whole facial aspect is characteristic and gives to the afflicted individual a most peculiar appearance. Albinism in the eye is but a part of a general lack of pigment in the whole of the body. Geoffrey St. Hilaire divided albinism into complete, incomplete and partial. Such a classification may, with propriety, be applied to the eye. The first two classes designate varying grades of pigment deficiency, whilst the last denotes a considerable reduction or total absence of pigment in a part of an organ, the rest being normal. Partial albinism is at times noted in the eye. Dark races seem more disposed to the affection than lighter races. The first published accounts of the trouble were in the beginning of the eighteenth century. Wafer in 1704 found the first albinos in Panama. Blumenbach in 1784 directed notice to the presence of albinism in Chamounix and was the first to draw attention to the fact that the reddish color of the pupil was due to this cause. Early travelers in Africa noted cases in Guinea, Algiers, Madagascar and the Congo. Quite a number were found on the African west coast, a few in Central Africa, and none on the east coast. DePaul in 1774 thought that albinism was found only in the regions ten degrees north and south of the equator and that it did not occur in Europe. Other beliefs that had wide acceptance for a time were that negroes mainly were affected and that female albinos were prolific, while the males were sterile.

It is well known that all the uveal pigment is not laid down at birth, that the irides are bluish, and during the first year become darker, the increased pigmentation taking place in the stroma. The choroid at birth, according to Kölliker, is also devoid of pigment.

Albinism has been noted as a family affection. Butler reported a family where three out of four children were albinos. The father and mother were normal but first cousins. Heredity is a prominent factor, though LaGleyze thinks that consanguinity is the most important factor in a majority of the cases. The transmission of albinism is not constant; it may skip one or more generations. In some families all the children are albinos, while in others some of them will be albinos and the rest normal. Blumenbach, Darwin and others found that albino animals are usually deaf. Absence of the organ of Corti and atrophy of the auditory centers were found in an albino dog by Pawitz. Whether there is any connection between the ocular and aural conditions is an open question. The attitude of the albino is striking, there is photophobia, the head is bent forward, the brow corrugated, the lids half-closed and the hand is often held to shield the eyes in a bright light. The conjunctiva is congested and the iris red, the radial striations being plainly seen. The color of the iris depends on the amount of light, red predominating when this is intense and violet gray in a dim light. There is nystagmus and frequently strabismus. The association of these is so frequent that a trinity of albinism, nystagmus and amblyopia is referred to (Seefelder). Nystagmus is usually horizontal with large oscillations, the rapidity being between 60 and 100 a minute. The movements may be rotary or mixed. Two explanations are given for the nystagmus, one that it is Nature's protection, saving the macular pigment from being "burnt up" by the intense light. The other is that it is due to amblyopia. The amblyopia which often cannot be explained by the refractive error has been shown recently to be due, at least in some cases, to an absence of the fovea. Fritsch found the fovea absent in an African albino. The pupil is small and dilates very little in diminished light. The reflexes are present but feeble. Corectopia is occasionally observed. With the ophthalmoscope the disc is reddish, at times deeper in color than the fundus; at other times it is gray. Usually the disc can only be located by the confluence of the retinal vessels (Mayerhausen). The choroidal vessels are made out beneath the retinal and no pigment is between them. In the most pronounced grades of albinism the hair, eyelashes and eyebrows are fine and downy and either perfectly white or possess a pinkish or yellowish tinge. The sclera is thin and offers slight resistance to the penetration of light. The skin of the lids, as well as other parts, is thin, soft and white. Visual acuity is always reduced, due to several factors, chief among which is lack of fixation and excess of light. The great diffusion of light and the inability of sustained fixation

must operate in preventing clear definition. If we accept the possibility of the absence of the fovea, then the amblyopia, the nystagmus and even the strabismus are at once explained. Color vision and the fields of vision are usually normal. Myopia is said to be the commonest refractive error. LaGleyze found no preponderance of myopia over hyperopia in his cases, but did find an astigmatism of about 4 D. usually present. In the milder grades of albinism the condition may improve as time goes on. Streatfeild quotes the case of a woman, aged 36, who stated that until she was 14 years old she was an albino, but from then on she became pigmented. This, of course, could only occur in incomplete albinism. In the complete forms no such change takes place. Blumenbach was the first to describe the absence of pigment in animals. Wharton Jones noted the absence of pigment in the hexagonal cells of the retina. In human eyes there is always a little pigment in these cells, though it is absent from the stroma. The supposition that the retinal epithelium is absent (Buzzi) has been disproved by anatomical examinations. Absence of pigment in the whole uveal tract and stroma of the choroid was found by Brucke. In 1905 Nettleship showed sections of the retina containing pigment only at the macular region. Partial albinism has been frequently described where a portion of the iris, choroid or retina was without pigment, the remainder being normal. Cases of absence of pigment in the fundus, while the iris, eyebrows and lashes were normal, are described by Nettleship. Thompson described a patient with ocular albinism, dark hair, eyebrows and lashes and a dark, muddy complexion. The eyes were perfectly albinotic, iris and fundal pigment absent. A myopia of 5 D. and nystagmus were present. Nothing was found in the family history and consanguinity was denied. The condition known as vitiligo of the iris, described by Müller as a form of partial albinism, is hardly correct. Numerous small, round or elongated white dots are scattered over the iris, corresponding with excavations in the stroma. Fuchs called attention to this rare condition and considered it almost pathognomonic of a previous attack of variola. Sautter saw two such cases in colored people, both of whom had had variola, and thinks his observations support the contention of Fuchs, but feels that further observations are necessary to establish the truth. The article by LaGleyze to which reference has frequently been made is probably the fullest ever written on the subject. The original, with four pages of bibliography, is to be found in the *Archives D'Ophtalmologie*, May, June and July, 1907. See also **Albinism**.

Tumors of the eye. The conjunctiva is at times the seat of con-

genital growths. Those most frequently seen are nævi, dermoids and fibro-fatty tumors. Nævi are benign but can take on malignancy. The great majority are pigmented. The pigmented areas are flat and consist of large endothelial cells. The pigment is both intra- and extra-cellular. Typical nævi resemble those of the skin. Cysts are frequently found in these tumors.

Wart-like growths of the conjunctiva or epithelial plaques have been described by Parsons who examined two such cases. They were in young patients and Parsons thought they were probably congenital.

Osteoma of the conjunctiva has been described by a large number of observers so consequently is not rare. Generally found in the

Dermoid Growth of the Cornea. (After Wood and Webb.)

Photograph of the upper growth (about 6 diameters). (*Ophthalmoscope*. Sept., 1910.)

upper-outer quadrant between the tendons of the superior and external recti. The growth is convex on the outer and flattened on the inner surface. It is not attached to the sclera but is freely movable over it. Around it is a covering of periosteum which is embedded in the deeper structures of the conjunctiva.

Dermoids occur on the eye-ball or in the surrounding tissues. They are divided according to their anatomical characteristics into lipodermoids and dermoid cysts. Lipodermoids are seen as yellowish hemispherical or more flattened tumors which occur usually at the limbus and most frequently on the temporal side and somewhat above the horizontal. They are found infrequently at any part of the limbus. They belong in reality to the conjunctiva which is but a modified skin. Rarely are sub-conjunctival dermoids found. A favorite situation is between the superior and external rectus. Dermoids of the caruncle are rare; Nobbe collected three such cases from

the literature. Dermoids of the cornea have likewise been observed. These tumors were early noted and described and Ryba in 1853 gave them their name. If dermoid cysts be excluded, dermoids of the orbit are rare. Wagenmann reported such a case where there was an apparent anophthalmia, and a similar one in a pig fœtus was reported by Sgrosso. Dermoids are true congenital anomalies and vary much in size and in behavior, often remaining small and causing no inconvenience except from a cosmetic point of view, while others take on growth and their removal becomes a necessity. They contain the elements of the skin, viz., stratified epithelium, hairs, sebaceous glands, sweat glands and fatty tissue. In a few cases hyaline cartilage was found (Talko, Rieke, Gallenga, Cohn), also pieces of bone (Wagenmann). The epithelium resembles true epidermis in having a horny layer, stratum lucidum, stratum granulosum, and a layer of prickle cells. Almost all dermoids contain hairs with well-developed follicles and sebaceous glands. The papillæ are badly developed. In the deeper layers areolar tissue, fat and medullated nerves are found. Accompanying anomalies are quite common in 65 per cent. of the cases (von Hippel). They are coloboma of the lids, corectopia, paresis of the external rectus and levator, coloboma of the iris and choroid, and changes in the disc and macula. Facial defects are hare-lip and cleft-palate. Where a coloboma of the lid is present a dermoid may be found upon the globe filling in the interval between the pillars of the coloboma. Dermoids usually remain quiescent up to the age of puberty, when with the development of the pubic hair they take on growth. The eye in most cases is otherwise normal but there are instances where it is congenitally deformed. Where the dermoids are covered by the lids the epithelium may be conjunctival and not epidermal. When the tumor protrudes between the lids and is exposed to irritation it becomes carnified.

The etiology of dermoids is variously explained. Failure of complete closure of the lids was the reason assigned by Ryba with the result that the conjunctiva becomes carnified. Dermoids are also considered as remains of a union of the eye ball with the amnion. Such a union must then occur in the first two months of fœtal life, as the closure of the palpebral fissure takes place in the third month, after which such a union would be impossible except in those cases associated with a lid coloboma where it could then happen later. von Hippel mentions the findings in a number of dermoids observed by various writers, and says that these cases are of great interest because important difficulties lay in the way of an explanation of the connection between dermoids and the remaining changes in the eye, staphyloma, anterior

synechiæ, etc., which most writers have not sufficiently observed. He cites the case of Leber and Cohn where there was a large corneal dermoid with acinous glands, hyaline cartilage, fat cells, where perforation of Descemet's membrane, adhesion of the fully-developed iris with the cornea, perforation of the lens capsule, adhesion of the lens with the corneal remains and iris and cataract, were found. Here the perforations prove, he thinks, that the pathological process bringing about these changes must have occurred relatively late in fœtal life, whereas dermoids must take origin in the first two months. Gallenga thought the origin of dermoids might be explained as remains of the fœtal plica semilunaris. Osburn considered the tumors as possible remains of the epiblast which forms the lens. Bernheimer in his case formulated two possibilities. (1) That there was softening of the cornea through absorption of the amniotic bands and secondary inflammation. (2) There was primarily a keratitis which on one side led to perforation and synechiæ and on the other to adhesion with the amnion. von Hippel rejects both explanations as improbable.

From the foregoing it is evident that a satisfactory and generally acceptable explanation of the genesis of dermoids has not been reached.

Fibro-fatty tumors, or lipodermoids, are always congenital. They are generally small in size and occupy the same sites as dermoids, the favorite situation being at the limbus between the insertion of the superior and external recti. They are generally of a yellow color. Careful examination usually reveals very minute cutaneous elements; at times but a single hair follicle or sebaceous gland is found. They may be quiescent till puberty and then start growing. Girls are said to be most frequently affected. They are conjunctival and not orbital growths. The same explanations as to etiology apply to lipodermoids and dermoids.

Congenital fibroma of the cornea must be an exceedingly rare condition. Mann reported a case in a young woman. It occupied the upper part of the cornea slightly toward the nasal side. "It was flattened and extended from just above the limbus to a little below the center of the cornea. The color was pinkish and the tumor vascular. Vision 1/100. The lid closed over the tumor." It had not enlarged since birth. A benign tumor was diagnosed and the pathologist reported that it was a fibroma.

Neuro-fibroma. This variety of tumor was found as a congenital growth in the left upper lid of a boy of 16 years by Weinstein. The lid was enormously thickened and covered the globe completely. The tumor had increased in size since birth and extended onto the temple. The eyeball was buphthalmic. A piece of the growth was excised and

proved to be a typical neuro-fibroma. Weinstein divides neurofibromata affecting the lids into three groups. (1) Neuro-plexiform; (2) Fibroma molluscum; (3) Unilateral hypertrophy of the face. He remarks that each form may be combined with buphthalmos. A brief summing up of the ten previously reported cases is given by him. Cosmetattos records a fibroma with congenital enlargement of the orbit. The tumor displaced the eye downwards and outwards. Optic nerve atrophied. The growth was solid and was removed through an incision in the upper lid. The specimen measured 4x2, 5x1 cm. and was found to consist of connective tissue with a few elastic fibers and some star cells in a fibrous capsule.

Teratoma. A teratoma is a tumor consisting of the derivatives of two or three of the germinal layers and contains organs or parts of organs and portions of the body. It is an exceedingly rare orbital condition. Only about 8 or 9 cases of true teratoma are found in literature. The tumor is an orbital one and is usually fairly large at birth, but grows rapidly causing great exophthalmos. The host of the tumor generally dies in a few weeks. The eyeball and optic nerve are normal, and have nothing to do with the origin of the growth. A true teratoma always consists of tissue elements from all three germinal layers. Von Hippel states that the formation of complete organs has never been met with. Mizou reported a rare case in which many parts of the body and organs were present with external preservation of the body form. He called the tumor a teratoid fœtus of the orbit. Mizou classifies these tumors thusly. Under atypical diplogenesis in which the parasite (the tumor) fastens itself on the head of the autosite (the child) there are four groups. (1) Epigratus. (2) Craniopagus parasiticus. (3) Janus parasiticus. (4) Dicephalus parasiticus. Orbital teratoma may be grouped, representing all the stages from the mixed tumor to the diplogenetic structures. (1) The fœtus is fastened by its pedicle in the orbit. (2) Parts of the body of a fœtus hang from the orbit. (3) A formless mass hangs from the orbit shown histologically to be derived from all three primitive layers. (4) A tumor mass in the orbit shown microscopically to be composed of different parts, cysts, bones, etc., having the characteristics of a mixed tumor and traceable to two primitive embryonic layers. Mizou's case was operated upon with perfect success. Since his article a case has been reported by Elliot and Ingraham, seen in a Hindu child. Operation was here performed, again with an uneventful recovery. Coulter and Coats in Jan., 1910, reported a teratoma of the orbit seen first when the child was three days old. Five days later the proptosis was marked and the cornea

and conjunctiva ulcerated. The tumor was tapped and three drachms of blood-stained fluid removed. The cornea ulcerated and the child died when three weeks old. The tumor filled the orbit, was lobulated and surrounded the optic nerve. A plaque of hyaline cartilage was present and there were numerous cysts. "The tumor consisted of a jumble of tissues derived from all these embryonic layers."

These tumors contain connective tissue of various types, skin, brain substance, intestine and intestinal gland, probably liver, respiratory mucous membrane, and cysts with a lining other than intestinal or respiratory mucous membrane. Showing the great rarity of these cases Coulter and Coats state that no case has been described in English literature for twenty-five years. The modified Marchand theory as given by von Hippel best explains the phenomena, as follows. In the beginning of the development of the embryo, one blastomere comes to lie on the faster growing organism and remains dormant, to develop at a later time, or begins at once in the early embryonic life to develop. Such cases where they are not far removed by cleavage from the original ovum are capable of developing complete organisms. The greater the number of divisions of the original cell before such a blastomere is segregated, the less potent it is of development. So we have such cells developing complete organisms or only parts thereof, or giving rise to more embryonic layers accordingly as it is near the first cleavage or distant from it.

Chondroma. A case of congenital chondroma at the inner lid angle is reported by Reuchlin. It was found in an infant of eight months, situated at the junction of the left nasal bone with the lateral cartilage. It did not recur after removal. The region of the caruncle was pushed forward by an ethmoidal mucocele.

Cysts of the iris. Cysts of the iris including all varieties are not rare but the number of the congenital cysts on record is small. Gallemaerts in 1907 collected only twenty-three examples. A small number of true dermoid cysts of the iris have been reported (Von Rosenweig, Lagrange). Many retention cysts are congenital. Congenital cysts occasionally occur with coloboma of the iris and other anomalous conditions of the eye. The theory as to the cause of these cysts which has been supported by Rosenweig, Lagrange, and Bardelli is that true congenital cysts of the iris are of epiblastic origin allied to dermoid tumors elsewhere. They are supposed to arise from some aberrant embryonic cells. Nadal suggests that these cells become separated from that part of the ectoderm from which the lens is developed during the first few weeks of fœtal life, and become implanted on the anterior wall of the secondary optic vesicle. After the development of the

mesoblastic tissues (iris etc.) they remain latent until roused into activity by some unknown influence. Nadal in reporting his case thought that it was different from the usual variety, the walls of which are lined with endothelium, whereas his was lined by a layer of epithelium made up of three, four and even five rows of cells with large nuclei. Schmidt-Rimpler suggested that the closure of one of the crypts of the iris gave origin to the cystic growths. This explanation received wide recognition. It does not, however, explain the cysts lined with epithelial cells. Gallemaerts in taking exception to Schmidt-Rimpler's hypothesis stated that the endothelium lining the crypts cannot give rise to the epithelium which many observers found in serous cysts of the iris. In view of the large number of crypts and the frequency of causes of their obliteration, as iritis, it is strange that cysts are not seen more frequently.—(W. F. H.)

BIBLIOGRAPHY.

Introduction.

Adair-Dighton—*Ophthalmoscope*, April, 1912.
Brown-Séquard—*Comptes rendus de l'Acad. des Sciences*, XCIV.
Deutschmann—*Klin. Monatsbl. f. Augenheilk.*, XVIII.
Fuchs—*Text Book*, 4th Am. Ed.
A. R. Gunn—*Ophthalmoscope*, April, 1912.
Hertwig—*Archiv f. Mikr., Anat.*, XLIV.
Lagleyze—*Archiv. d'Ophtal.*, May, June, July, 1907.
Leber and Addario—*Archiv f. Ophthal.*, XLVIII.
Loeb—*Annals of Ophthal.*, Jan., 1909.
Nieden—*Klin. Monatsbl. f. Augenheilk.*, XIX.
Pflugk—Quoted by Loeb—*Annals of Ophthal.*, Jan., 1909.
Parsons—*Pathology*, Vol. III.
Rolleston—*British Jour. of Children's Diseases*, March, 1911.
Seefelder—*Archives of Ophthal.*, July, 1910.
Stephenson—*Ophthalmoscope*, May, 1910.
Tobias—*Klin. Monatsbl. f. Augenheilk.*, April, 1911.
Von Hippel—*Graefe-Saemish Handbuch*, 1900.

Microblepharon and Ablepharon.

Fuchs—*Archiv f. Ophthal.*, XV, 1885.
Gallenga—Nagel's *Jahresbericht*, 1892.
Seiler—*Beob. Ursprüngl. Bildungsfehler der Augen*, Dresden, 1833.

Coloboma of the lids.

Bruns—*Handbuch d. Prakt. Chir.*, 1859.
Pollailon—*Gazette des Hôpitaux*, 1874.
Van Duyse—*Ann. d'Ocul.*, LXXXVIII. *Encycl. Française*, II, 1905.
Nance—*Chicago Ophthal. Society*, 1907.
Zielendorf—*Wiener Klin. Woch.*, 1894.
Tyrrell, Doyne—*Trans. Ophthal. Soc., U. K.*, XXIII.
Treacher Collins—*Trans. Ophthal. Soc., U. K.*, XX-XXII-XXV.
Harman—*Trans. Ophthal. Soc., U. K.*, XXIV.
Nuel—*Archiv. d'Ophtal.*, I.

Von Hippel—*Graefe-Saemish Handbuch*, 1900.
Dor—*Rev. Gén. d'Ophtal.*, 1888.
Nicolini—*Thèse de Lyon*, 1888.
Parsons—*Pathology*, Vol. III.
De Vries—*Tydschr. v. Gen., Aug.*, 1908.

Epicanthus.

Steinheim—*Centralb. f. prak. Augenheilk.*, 1898, S. 249.
Von Ammon—*Ammons Zeitsch.*, I, 1831.

Ankyloblepharon.

Bunzel—*Prager Med. Woch.*, 1890.
Coover—*Jour. Amer. Med. Ass'n.*, July 30, 1910.
Hasner—*Prager Zeitsch. f. Heilkunde*, 1882.
Reis—*Zeitsch. f. Augenheilk.*, June, 1908.
Webster—*Beiträge zur Augenheilk.*, XXXIV.
Wintersteiner—*Centralbl. f. Prak. Augenheilk.*, XXII.
Wintersteiner—*Archiv f. Ophthal.*, Bd. LIX, heft 2.

Cryptophthalmia.

Bach—*Archiv f. Ophthal.*, XXXII, 1895.
Collins—*Lancet*, 1900.
Coover—*Jour. Am. Med. Ass'n.*, July 30, 1910.
Fuchs—*Wiener Klin. Woch.*, 1889.
Ginsberg—*Westn. Ophthal.*, No. 4, 1911.
Hocquart—*Archiv. d'Ophtal.*, I.
Eberhardt—*Ophthal. Record*, Jan., 1911.
Karmann—*Archiv f. Kinderheilk.*, XVIII.
Otto—*Wiener Klin. Woch.*, 1893.
Van Duyse—*Annales d'Oculistique*, CI.—*Archiv. d'Ophtal.*, XIX.
Zehender—*Klin. Monatsbl. f. Augenheilk.*, X.

Distichiasis.

Ischreyt—*Centralbl. f. Pkt. Augenheilk.*, XXII.
Kuhnt—*Zeitsch. f. Augenheilk.*, II.
Traquair—*Ophthal. Review*, May, 1912, p. 138.
Westhoff—*Centralbl. f. Augenheilk.*, XXIII.
Casey A. Wood—*Trans. Chicago Ophthal. Soc.*, 1898.

Muscle anomalies.

Coover—*Trans. Colo. Ophthal. Soc.*, Feb. 20, 1909.
Heuck—*Klin. Monatsbl. f. Augenheilk.*, 1879; *Klin. Monatsbl. f. Augenheilk*, XVIII.
Harman—*Trans. Ophth. Soc. U. K.*, Vol. XXV, 1905.
Coburn—*Med. Record*, Aug., 1904.
Babonneix and Harvier—*Gaz. des Hôpitaux*, Nov., 1908.
Levinsohn—*Zeitsch. f. Augenheilk.*, XVII, No. 4.
Axenfeld and Schurenberg—*Klin. Monatsbl. f. Augenheilk.*, 1901.
Franke—*Klin. Monatsbl. f. Augenheilk.*, Nov., 1909.
Stephenson—*Ophthalmoscope*, Sept., 1908.
Paterson—*Ophth. Rev.*, May, 1910.
Cooper—*Brit. Med. Journ.*, April 16, 1910.
Thompson and Sauter—*Ophth. Rev.*, June, 1912.
Huebner—*Berlin Med. Soc.*, May, 1910.
Willbrand and Saenger—*Die Neurol. des Auges*, Wiesbaden, 1900.
Dieffenbach—*Das Schielen*, Berlin, 1842.
Pflüger—*Klin. Monatsbl. f. Augenheilk.*, XIV.
Lawford—*Trans. Ophth. Soc. U. K.*, VIII.
Ahlström—*Beitr. z. Augenheilk.*, XVI.

Uthoff—*Jahresbericht d. Schöler. Augenklinik.*, 1881-1882.
Steinheim—*Klin. Monatsbl. f. Augenheilk.*, XV.
McCubbin—*Am. Jour. Ophthal.*, March, 1911.
Werner—*Trans. Ophthal. Soc. U. K.*, XXIV.

Retraction syndrome.

Heuck—*Klin. Monatsbl. f. Augenheilk.*, 1879.
Bahr—*Bericht d. Ophth. Gesellsc.*, Heidelberg, 1896.
Collins—*Brit. Med. Jour.*, Sept., 1899.
Wolff—*Archiv. of Ophth.*, 1900, p. 297.
Peschel—*Centralbl. f. Prakt. Augenheilk.*, Jan., 1904.
Duane—*Archiv. of Ophth.*, Vol. XXXIV, No. 2.
Duane—*Archiv. of Ophth.*, 1900, p. 476.
Green, J., Jr.—*Trans. Acad. of Ophth. and Laryng.*, 1907.
Green, J., Jr.—Personal communication.

Opacities of the cornea.

Armargnac—*Recueil d'Ophtal.*, XXXIII, p. 142.
Chance—*Archiv. Ophth.*, Nov., 1908.
Sallfner—*Archiv f. Augenheilk.*, Vol. XLV., No. 2.
Tweedie—*Ophth. Record*, March, 1911.
Von Hippel—Graefe's *Archiv*, LXVIII, May 17, 1908.
Komoto—*Klin. Monatsbl. f. Augenheilk.*, XLVII, II, 4.
Mohr—*Klin. Monatsbl. f. Augenheilk.*, 48, II, Sept., 1910.
Parsons—*Pathology*, Vol. III.
Seefelder—German Edition, *Archiv. of Ophth.*, Vol. LIII, No. 2.
Treacher Collins—*Trans. Ophth. Soc. U. K.*, XXV.
Braun—*Dissertation*, Heidelberg.
Hilbert—*Klin. Monatsbl. f. Augenheilk*, XXX.
Marcus Gunn—*Trans. Ophth. Soc. U. K.*, XVIII.
Peters—*Klin. Monatsbl. f. Augenheilk.*, XLIV.
Von Hippel—*Graefe-Saemisch Handbuch*, 1900.

Congenital anterior staphyloma.

Bernheimer—*Archiv f. Augenheilk.*, Bd., XVIII, 1887.
Coats—*Ophthalmoscope*, Nov., 1909, p. 724.
Coats—*Ophthalmoscope*, April, 1910.
Collins—*Trans. Ophth. Soc. U. K.*, Vol. 29, 1909.
Crampton—*London Med. Gaz.*, 1840.
Hirschberg and Birnbacher—*Centralbl. f. Augenheilk.*, X.
Kruckow—*Archiv f. Ophth.*, XXX, I.
Lawson and Coats—*Trans. Ophth. Soc. U. K.*, XXVI.
Parsons—*Pathology*, Vol. III.
Parsons—*Trans. Ophth. Soc. U. K.*, XXIV.
Steinheim—*Centralbl. f. Augenheilk.*, XXI, 1897.
Stephenson—*Ophthalmoscope*, April 1, 1912.
Swanzy—*Dublin Quarterly Jour. Med. Sciences*, May, 1871.
Westhoff—*Centralbl. f. Augenheilk.*, XXIII.
Leber and Addario—*Archiv f. Ophth.*, XVIII, 1.
Pincus—*Inaugural Dissertation*, Koenigsberg, 1887.
Runte—*Archiv f. Ophth.*, XLVIII.
Schiess-Gemuseus—*Archiv f. Ophth.*, XXXX, 3.
Schoebl—*Centralbl. f. Augenheilk.*, 1886.
Treitel—*Archiv f. Ophth.*, XXII, 2

Anophthalmia.

Bartscher—*Ann. d'Ocul.*, XXXVII, 1887.
Bernheimer—*Archiv f. Ophth.*, LXV, I, p. 99.
Giffo—*L'Ophtal. Provin.*, I-IV, April, 1907.

Gradenigo—*Ann. d'Ocul.*, LXVI, 1870.
Greeff—*Archiv f. Augenheilk.*, LI.
Hoppe—*Archiv f. Augenheilk.*, XXXIX, 1899.
Klein—*Ophth. Gesell.*, Wien., May, 1908.
Schiperkaja—*Russky Vratsch*, 1909.
Treacher Collins—*Royal London Ophth. Hosp. Rep.*, XI, 1887.
Von Hippel—*Graefe-Saemisch*, 1900; *Archiv f. Ophth.*, XLVII, 1898.
Van Duyse—*Archiv. d'Ophtal.*, XIX, 1899; *Encyc. Française*, II, 1905.
Wicherkiewicz—*Klin. Monatsbl. f. Augenheilk.*, 1878.
Boulai—*La Clin. Ophtal.*, 1911.
Collins and Parsons—*Trans. Ophth. Soc. U. K.*, XXIII.
Von Hippel—*Archiv f. Ophth.*, LXIII, 1.

Microphthalmia.

Bach—*Archiv f. Ophth.*, XLV, 1898.
Cosmettatos—*Ann. d'Ocul.*, CXXXIX.
K. Orlow—*Westn. Ophth.*, 1910, No. 12.
Lafon—*Archiv. d'Ophtal.*, XXVII.
Landmann—*Centralbl. f. Prakt. Augenheilk.*, XXXII, p. 131.
Mayou—*Trans. Ophth. Soc. U. K.*, Jan., 1908.
Pagenstecher—*Bericht d. Oph. Gesell.*, Aug., 1911.
Parsons and Coats—*Brain*, XXIX, 1906.
Coats—*Ophthalmoscope*, Oct., 1910.
Coover—*Trans. Colo. Ophth. Soc.*, Nov., 1909.
Cunningham—*Ophthalmology*, Oct., 1908.
Pyle—*Sec. Ophth. Col. P. and S.*, Phila., Jan., 1908.
Kitamura—*Klin. Monatsbl. f. Augenheilk.*, XLIV.
Rochon-DuVigneaud and Coutela—*Archiv. d'Ophtal.*, XXVII.
Rust—*Cleveland Med. Jour.*, IX, 1910.
Beer—*Das Auge*, 1813.
Falchi—*Ann. di Ottal.*, XIII.
Hess—*Archiv f. Ophth.*, XXXIV, 3, XXXVI, XXXVIII.
Hanke—*Archiv f. Ophth.*, LVII.
Himly—*Ophth. Beob. Krankh. & Missb. d. Mensch. Aug.*, 1843.
May and Holden—*Archiv. of Ophth.*, Vol. XXXV, pp. 424.
Martin—*Dissertation*, Erlangen, 1888.
Loeb—*Ann. Ophth.*, Jan., 1909.
Page—*Lancet*, 1874.
Rava—*Ann. di Ottal.*, IX.
Reber—*Ann. d'Ocul.*, CXIX.
Treacher Collins—*Trans. Ophth. Soc. U. K.*, XIII.
Van Duyse—*Encyc. Française*, 1905.
Von Hippel—*Archiv f. Augenheilk.*, Vol. LII; *Archiv f. Ophth.*, LV; *Graefe-Saemisch*, 1900.
Wessely—*Wien. Med. Woch.*, Feb., 1912.

Microphthalmia with cyst.

May and Holden—*Archiv f. Augenheilk.*, LVIII, 1.
Wicherkiewicz—*Klin. Monatsbl. f. Augenheilk.*, Feb., 1910.
Loehlein—*Zeitsch. f. Augenheilk.*, May, 1912.
Kitamura—*Klin. Monatsbl. f. Augenheilk.*, XLIV.
Natanson—*Archiv f. Augenheilk.*, LXVII, Jan. 21, 1908.
Haab—*Archiv f. Ophth.*, Bd. XXIV, heft II, S. 257, 1878.
Coats—*Ophthalmoscope*, Nov. 1, 1909.
Arlt—*Anzeiger d. Kinderkranken Gesellschaft in Wien*, 1885.
Kundrat—*Wiener Med. Blätter*, 1885, 1886.
Ginsberg—*Archiv f. Ophth.*, XLVI, 2, 1898.
Pichler A.—*Zeitsch. f. Augenheilk.*, Bd. III, S. 570, 1900.
Gallemaerts—*Rev. Gen. d'Ophtal.*, I, XII, 1893.
Czermak—*Wiener Klin. Woch.*, S. 488, 1891.
Mitvalsky—*Archiv f. Augenheilk.*, Bd. XXV, S. 218, 1892.

Dyson—*Year Book*, 1905.
Connor—*Archiv. of Ophth.*, XXXV, 1.
De Vries—*Tydsch. v. Gen.*, Aug., 1908.
Van Duyse—*Annales d'Oculistique*, LXXXVI—*Encyc. Française*, 1905.
Ewetsky—*Dissertation, Dorpat.* 1886.
Parsons—*Pathology*, Vol. III.
Von Hippel—*Graefe-Saemisch Handb.*, 1900—*Archiv f. Ophth.* XLV, 2; *Archiv f. Ophth.*, LV, 3.
Rindfleisch—*Archiv. f. Ophth.*, XXXVII, 3.
Bergmeister—*Archiv. f. Ophth.*, Bd. LXXXV.
Treacher Collins—*Royal London Ophth. Hosp. Reports*, XII; *Trans. Ophth. Soc. U. K.*, XIII.
Hess—*Archiv f. Ophth.*, XLII, 3; *Archiv. f. Ophth.*, XLI.
Mayou—*Trans. Ophth. Soc. U. K.*, XXIV.
Cruise—*Trans. Ophth. Soc. U. K.*, XXV.

Buphthalmus.

Axenfeld—*Klin. Monatsbl. f. Augenheilk.*, XLI.
Bondi—*Wiener Med. Presse*, 1898.
Cabannes—*La Clin. Ophtal.*, Sept., 1909.
Coats—*Ophthalmoscope*, April, 1910.
Horner—*Krankh. des Aug. im Kindersalter*—Gerhard's *Handbuch.*
Loeb—*Annals Ophth.*, Jan., 1909.
Mayou—*Trans. Ophth. Soc. U. K.*, Vol. 30, Fasc. 2.
Parsons—*Pathology*, Vol. III.
Spielberg—*Klin. Monatsbl. f. Augenheilk.*, Oct., 1911.
Van Duyse—*Encyc. Française*, II, 1905.
Weinstein—*Klin. Monatsbl. f. Augenheilk.*, Nov., 1909.
Gross—*Thèse de Paris*, 1897.
Reis—*Archiv f. Ophth.*, LX, I.

Cyclopia.

Ahlfeld—*Die Missbil. des Menschen*, Leipzig, 1880.
Bock—*Klin. Monatsbl. f. Augenheilk.*, XXVII.
Dareste—*Recherches s. l. Production Artif. des Monstruos*, 1877.
De Vries—*Nederl. Tidjs. Geneesk.*, I, p. 1426.
Dursy—*Zur Entwick. des Kopfes, Tübingen*, 1869.
Gabrieledes—*Archiv. d'Ophtal.*, XVI.
Huschke—Müller's *Archiv f. Anat. u. Phys.*, 1832.
Lewis—*Anat. Record*, III, No. 4.
Natanson—*Klin. Monatsbl. f. Augenheilk.*, March, 1909.
Panum—Virchow's *Archiv*, LXXII.
Peunow—Nagel's *Jahresbericht*, 1889.
Roland—*Gaz. des Hôpitaux*, No. 6, 1908.
Seefelder—*Archiv f. Ophth.*, Bd. LXVIII, 1908.
Taranetsky—*Archiv f. Ophth.*, XII.
Van Duyse—*Archiv. d'Ophtal.*, 1909; *Archiv. d'Ophtal.*, XVIII.
Von Hippel—*Graefe-Saemisch Handb.*, 1900.
Stockard—*Science*, Oct., 1908.

Persistent pupillary membrane.

Coats—*Ophthalmoscope*, Oct., 1910.
Collins—*Trans. Ophth. Soc. U. K.*, XIII; *Researches into the Anatomy and Path. of Eye*, 1896.
Von Hippel—*Archiv f. Ophth.*, Bd. LX, 905; Graefe-Saemisch, 1900.
Marcrocki—*Archiv f. Augenheilk.*, Bd. XIV.
Zirm—*Klin. Monatsbl. f. Augenheilk.*, Bd. XXVIII.
Traltner—*Klin. Monatsbl. f. Augenheilk.*, Bd. XXIX.
Vossius—Deutschmann's *Beitrag z. Augenheilk.*, Bd. 1, hft. 9.
Wüstefeld—*Zeitsch. f. Augenheilk.*, Bd. IV, 1900.
Schleich—*Wiener Med. Presse*, 1886.

Uhthoff—*Jahresbericht d. Schoeler's Augenkrank.*, 1882.
Massey—*Ophthalmoscope*, Nov., 1908.
Schubert—*Bericht d. Ophth. Gesellsch. z. Heidelberg*, 1892.
Meyerhauser—*Zeitsch. f. Vergleich. Augenheilk.*, II; *Klin. Monatsbl. f. Augenheilk.*, XXIV.
Beck—Ammon's *Zeitsch.*, Bd. I.
Ballantyne—*Trans. Ophth. Soc. U. K.*, XXV.
Rumschewitsch—*Archiv f. Augenheilk.*, XX; *Archiv f. Augenheilk.*, XLVI.
Michel—*Archiv f. Ophth.*, XXVII, 2.
Franke—*Archiv f. Ophth.*, XXX, 4.
Wintersteiner—*Archiv f. Ophth.*, Bd. LVII; *Wiener Klin. Woch.*, 1893.
Cohn—*Centralbl. f. Augenheilk.*, V.
Hasner—*Prager Med. Woch.*, 1883.
Wicherkiewicz—*Archiv f. Ophth.*, XXXIV, 4.
Van Duyse—*Ann d'Oculistique*, XXII; *Encycl., Franc.*, II, 1905.
Samelsohn—*Centralbl. f. Augenheilk,*, IV.
Silcock—*Trans. Ophth. Soc. U. K.*, XV.

Aniridia.

Gutfreund—*Wiener Klin. Woch.*, 1908.
Brunhuber—*Klin. Monatsbl. f. Augenheilk.*, XV, 1877.
Tokkus—*Dissertation*, Strassburg, 1888.
Von Hippel—*Graefe-Saemisch Handb.*, 1900.
Rindfleisch—*Archiv f. Ophth.*, XXXVII, 3; XXXVIII, 1.
Foster—Ref. v. Adelsdorff in *Archiv f. Augenheilk.*, XXIX.
De Benedetti—*Ann. di Ottalm.*, XV.
Collins—*Ophth. Rev.*, X, 1891.
Brailey—*Trans. Ophth. Soc. U. K.*, X, 1890.
De Schweinitz—*Trans. Am. Ophth. Soc.*, 1891.
Dennis—*Archiv. of Ophth.*, 1906, 6.
Lembeck—*Dissertation*, Halle, 1890.
Scalinci—*Annali di Ottalmologia Fasc.*, 7-8-9, 1904.
Van Duyse—*Archiv. d'Ophtal.*, XXVII, 1.
Seefelder—Graefe's *Archiv*, 70, 1.
Hopf—*Dissertation*, Jena, 1900.
A. H. Pagenstecher—*Archiv f. Ophth.*, LV, 1.
A. H. Pagenstecher—*Klin. Monatsbl. f. Augenheilk.*, IX.
Bergmeister—*Archiv f. Ophth.*, LIX, 1.
De Beck—*Trans. Am. Ophth. Soc.*, 1894.
Hamilton—*Ophthalmoscope*, May, 1903.
Galezowski—*Rec. d'Ophtal.*, 1880.
Vossius—*Klin. Monatsbl. f. Augenheilk.*, XXI.
Coats—*Ophthalmoscope*, Oct., 1910.
Collins—*Ophth. Rev.*, Vol. X.
Hess—*Klin. Monatsbl. f. Augenheilk.*, Bd. XXX.
Ryerson—*Canadian Pract. and Rev.*, Sept., 1911, p. 548.

Polycoria.

Franke—*Klin. Monatsbl. f. Augenheilk.*, XXVII.
Lang & Collins—in Norris and Oliver, 1896.
Mittendorf—*Trans. Am. Ophth. Soc.*, 1884.
Schapringer—*New York Med. Jour.*, 1897.
Polte—*Archiv. f. Augenheilk.*, XLVIII.
Rumschewitsch—*Medicyna*, 1881; *Rev. Gèn. d'Ophtal.*, III; *Westnik Ophth.*, 1887.
Manz—*Trans. Intern. Cong.*, 1888.
Treacher Collins—*Trans. Ophth. Soc. U. K.*, XV.
Von Ammon—*Klin. Darstellungen*, 1841.

Corectopia.

Wiede—*Malformations of the Organs of Sight*, 1862.
Lindner—*Wiener Med. Woch.*, 1895.
Van Duyse—*Ann. d'Oculistique*, XV; *Encyc. Française*, II, 1905.

Von Hippel—*Archiv f. Ophth.*, LI; Graefe-Saemisch, 1900.
Samelsohn—*Centralbl. f. Med. Wiss.*, 1875; *Berliner Klin. Woch.*, 1875.
Von Ammon—*Klin. Darstellungen*, III, Berlin, 1841.
Damianos—*Beiträge z. Augenheilk.*, XXIX.
Rindfleisch—*Bericht der Ophth. Gesellsch. zu Heidelberg*, 1892.
Best—*Archiv f. Ophthalmol.*, XL, 4.
Breitbarth—*Dissertation*. Giessen, 1878.
Parsons—*Pathology*, Vol. III.
Pufahl—*Centralbl. f. pkt. Augenheilk.*, III, 1879.

Ectropion uveæ.

Okuse—*Klin. Monatsbl. f. Augenheilk.*, Feb., 1911.
Enslin—*Archiv f. Augenheilk.*, LI.
Bock—*Klin. Monatsbl. f. Augenheilk.*, XXVI.
Reis—*Zeits. f. Augenheilk.*, Dec., 1909.

Cataract.

Alt—*Am. Jour. Ophth.*, Aug., 1899.
Hulke—*Ophth. Hosp. Rep.*, 1.
Nuel—*Archiv. d'Ophtal.*, Jan., 1899.
Pagenstecher—*Bericht d. Oph. Gesellsch.*, 1911; *Ophthalmology*, Oct., 1911.
H. Knapp—*Archiv. of Ophth.*, 1906, p. 141.
Deutschmann—*Archiv f. Ophth.*, Bd. XXXII, 2.
Beselin—*Archiv f. Augenheilk.*, Bd., XVIII.
Schirmer—*Archiv f. Ophth.*, *Bd.* XXXV, 1.
Lawford—*Royal London Ophth. Hosp. Rep.*, Vol., XII.
Hess—*Archiv f. Ophth.*, XXXIX, 1.
Treacher Collins—*Lancet*, Dec., 1894; *Trans. Ophth. Soc. U. K.*, XV.
Von Hippel—*Archiv f. Ophth.*, XLI, 3 and LIV, 1.
Bach—*Archiv f. Ophth.*, XLIII, 3.
Heinzel—*Archiv f. Ophth.*, XLVIII, 3.
Schirmer—*Archiv f. Ophth.*, XXXVI, 4.
Oncken—*Dissertation*, Marburg, 1901.
Hess—*Graefe-Saemisch Handb.*, VI, 2, 1905.
Nettleship and Ogilvie—*Ophth. Soc. U. K.*, June 14, 1906.
Burton Chance—*Archiv. of Ophth.*, 1907, p. 505.
Parsons—*Pathology*, Vol. III.
Crampton—*Ophth. Soc. College Phys. and Surg.*, Phila., Jan. 20, 1910.
Kipp—*Am. Jour. Ophth.*, Aug., 1909.
Knies—*Archiv f. Ophth.*, XXIII, 1.
Von Ammon—*Zeit. f. Ophth.*, III.
Pilz—*Prager Vierteljahresschrift*, XXIV.
Müller—*Archiv f. Ophth.*, II, 2.
Gilbert—*Graefe's Archiv. f. Ophth.*, Feb., 1912.

Ectopia lentis.

Adams—*Trans. Ophth. Soc. U. K.*, Fasc., 3, 1909.
Bowman—*Royal London Ophth. Hosp. Rep.*, Vol. V.
Dixon—*Royal London Ophth. Hosp. Rep.*, Vol. I, 1857.
Dorsch—*Dissertation*, Marburg, 1900.
Graefe—*Archiv f. Ophth.*, I and II.
A. R. Gunn—*Ophthalmoscope*, Apr., 1912.
Marcus Gunn—*Trans. Ophth. Soc. U. K.*, Vol. IX.
Jackson—*Colo. Ophth. Soc.*, Nov., 1911.
Knapp—Quoted by Lang and Collins in Norris and Oliver.
Lewis—*Archiv f. Ophth.*, XXXIII.
Morton—*Royal London Ophth. Hosp. Rep.*, Vol. IX.
Stroud—*Trans. Ophth. Soc. U. K.*, Vol. 31 Fasc., II.
Zani—*Ann. di Ottalmologia*, XXXVIII Fasc., 4.

Lenticonus.

Pergens—*Archiv f. Augenheilk.*, XXXV.
Collins—*Sec. Ophth. Am. Med. Ass'n.*, 1908.
Patry—*Sur l'Histologie et l'etiologie du Lenticone Posterieur*, Genêve, 1906.
Mayou—*Trans. Ophth. Soc. U. K.*, XXIV; *Trans. Ophth. Soc. U. K.*, XXVIII, Fasc., 1.
Webster—*Archiv f. Augenheilk.*, IV.
Van der Laan—*Period de Oftalm.*. 1880.
Mohr—*Klin. Monatsbl. f. Augenheilk.*, Sept., 1910.
F. Meyer—*Centralbl. f. Augenheilk.*, XI.
Eiseck—*Klin. Monatsbl. f. Augenheilk.*, XXX.
Cramer—*Klin. Monatsbl. f. Augenheilk.*, XXXIV.
Mitvalsky—*Centralbl. f. Augenheilk.*, XV.
Knapp—*Archiv f. Augenheilk.*, XXII.

Coloboma of the iris.

Rössler—*Archiv f. Ophth.*, LXXX.
Jackson—*Colo. Ophth. Soc.*, Nov., 1908.
Coover—*Colo. Ophth. Soc.*, Nov., 1909.
Czapodi—Nagel's *Jahresbericht*, 1885.
Theobald—*Am. Jour. Ophth.*. 1888.
Simonson—*Dissertation*, Berlin, 1892.
McGillivray—*Ophth. Rev.*, XVII.
Zimmermann—*Archiv f. Ophth.*, LXVI, H. 2.
Heyl—*Ann. d'Ocul.*, LXXVII.
Macroki—*Archiv f. Augenhl.*, XIV.
Von Hippel—*Archiv f. Ophth.*, XVII, 1; *Graefe-Saemisch*, 1900; *Archiv f. Ophth.*, LII, 3.
Rachlmann—*Bibl. Med.*, 1897.
Schiess-Gemuseus—*Klin. Monatsbl. f. Augenheilk.*, XXV.
Nuel and Leplat—*Ann. d'Ocul.*, CI.
De Vries—*Archiv f. Ophth.*, LVII., 3.
Yamaguchi—*Klin. Monatsbl. f. Augenheilk.*, XLV, 2.
Gilbert—*Zeitsch. f. Augenheilk.*, Jan., 1907.
Purtscher—*Centralbl. f. Augenheilk.*, Apr., 1910.
Faber—*Tydschr. f. Gen.*, Aug., 1908.
Gescheidt—*Dissertation*, Leipzig, 1831.
Bock—*Die Angeb. Col. des Aug.* Wien., 1893.
Rumschewitsch—*Archiv f. Ophth.*, XXXVII, 1.
Van Duyse—*Encyc. Française*, II, 1905.
Steinheim—*Centralbl. f. Augenheilk.*, IX.
Rindfleisch—*Archiv f. Ophth.*, XXXVIII, 1.

Coloboma of the lens.

Schiess-Gemuseus—*Archiv f. Ophthl.*, XXXI; *Klin. Monatsbl. f. Augenheilk.*, IX.
Bock—*Die Angeb. Col. des Aug.*, 1893.
Bock—*Colobome du Cristallin. Encyc. Française*, T. II.
Christen—*Archiv f. Augenheilk.*, 1893.
Cissel—*Klin. Monatsbl. f. Augenheilk.*, XXVIII.
Collins—*Trans. Ophth. Soc. U. K.*, XIII.
Collins—*Royal London Ophth. Hosp. Rep.*, Vol. XIII.
Doyne—*Trans. Ophth. Soc. U. K.*, XI.
Hess—*Bericht der Oph. Gesell.*. 1892; *Klin. Monatsbl. f. Augenheilk.*, Bd. XXX; *Klin. Monatsbl. f. Augenheilk.*, XXXIV.
Isakowitz—*Archiv f. Augenheilk.*, June, 1907; *Archiv f. Augenheilk.*, Bd. LIX, 1908.
Kämpffer—*Archiv f. Ophth.*, XLVIII.
Lang—*Trans. Ophth. Soc. U. K.*, X.
Marple and Coburn—*Sec. Ophth. N. Y. Acad. Med.*, March 21, 1910.
Narkiewicz-Jodko—*Centralbl. f. Augenheilk.*, I.
Rogman—*Archiv. d'Ophtal.*, XVII.

Schaumberg—*Dissertation*, Marburg, 1882.
Sohby—*Ophthalmoscope*, March, 1913.
Toldt—Deutschmann's *Beiträge z. Augenheilk.*, Bd. V., 1902.
Verderame—*Archiv f. Augenheilk.*, Apr., 1907.
Vossius—*Beiträge z. Augenheilk.*, IX.
Wessely—11th Int. Cong. on Ophth., (*Archiv f. Augenheilk.*, LXIV, No. 1).

Coloboma of the ciliary body.

Alt—Personal Communication.
Bock—*Die Angeb. Col. des Aug.*, Wien., 1893.
Erdmann—*Zeitsch f. Natur. u. Heilk.*, IV, 1826.
Hess—*Archiv f. Ophth.*, XLII, 3.
Nuel and Leplat—*Ann. d'Ocul.*, CI.
Van Duyse—*Encyc. Française*, II, 1905.

Coloboma of the choroid and retina.

Botteri—*Klin. Monatsbl. f. Augenheilk.*, July, 1910.
Meisner—*Graefe's Archiv.*, *Vol., 79 pt. 2.*
Derby—*Ophthalmology*, July, 1907.
Bradburne—*Ophthalmoscope*, Sept., 1911.
Tatham Thompson—*Trans. Ophth. Soc. U. K.*, XIX.
Landmann—*Archiv. of Ophth.*, 1905.
Alexander—*Ophthalmology*, Apr., 1910.
Litten—Virchow's *Archiv*, LXVII.
Nuel and Leplat—*Ann. D'Ocul.*, CI.
Hirschberg—*Centralbl. f. Augenheilk.*, VIII, and V.
Saemisch—*Klin. Monatsbl. f. Augenheilk.*, V.
Lieberkuhn—*Archiv f. Anat. u. Phys.*, 1879.
Von Hippel—*Graefe-Saemisch Handb.*, 1900; *Archiv f. Ophth.*, LII.
Van Duyse—*Archiv D'Ophtal.*, XVI; *Encyc. Française*, II, 1905.
Frost—*Trans. Ophth. Soc. U. K.*, XIII.
Bock—*Die Angeb. Col. des Aug.*, 1893.
Bach—*Archiv f. Ophth.*, XLV.
Randall and de Schweinitz—*Archiv f. Augenheilk.*, XIX.
Schmidt-Rimpler—*Archiv f. Ophth.*, XXIII & XXVI.
Lindsay Johnson—*Archiv f. Augenheilk.*, XXI.
Hess—*Archiv f. Ophth.*, XLII—XXXIV 3, XXXVI; *Klin. Monatsbl. f. Augenheilk.*, XXX.
Hänel—*Dissertation*, Erlangen, 1886.
Mittelstädt—*Archiv f. Augenheilk.*, XIX.
Haab—*Archiv f. Ophth.*, XXIV.
Deutschmann—*Klin. Monatsbl. f. Augenheilk.*, XIX.
Pinto—*Archiv f. Augenheilk.*, XIII.
Steinhein—*Centralbl. f. Augenheilk.*, IX.
Thalberg—*Archiv f. Augenheilk.*, XIII.
Pause—*Archiv f. Ophth.*, XXIV.
Van Reuss—*Archiv f. Ophth.*, XXVII, 4.
Pfanmüller—*Dissertation*, Giessen, 1894.
Rindfleisch—*Klin. Monatsbl. f. Augenheilk.*, XXXII.
Tartuferi—Nagel's *Jahresbericht*, 1884.
Eversbusch—*Bericht d. Ophth. Gesellsch. z. Heidelb.*, 1883.
Lang—*Trans. Ophth. Soc. U. K.*, VI.
Höltzke—*Archiv f. Augenheilk.*, XII.

Coloboma of the macula.

Bock—*Die Angeb. Colob. des. Aug.*, Wien, 1893.
Johnson—*Archiv f. Augenheilk.*, XXI, 1890.
Kimpel—*Archiv f. Augenheilk.*, XXXVII.
Wiethe—*Archiv f. Augenheilk.*, XIV.
Schmidt Rimpler—*Archiv f. Ophth.*, XXVI, 2.

Kastalsky—*Archiv f. Augenheilk.*, XXXVI.
Schnabel—*Wiener Med. Blaetter*, 1884.
Von Hippel—*Graefe-Saemisch*, 1900.
Van Duyse—*Encyc. Française*, II, 1905.
Hansell—*Trans. Am. Ophth. Soc.*, 1909.
Reber—*Annals Ophth.*, Apr., 1908.
Zimmerman—*Klin. Monatsbl. f. Augenheilk.*, XXXV.
Hess—*Archiv f. Ophth.*, XXXVI.
Silcock—*Trans. Ophth. Soc. U. K.*, XX, 1900.
Deyl—International Cong., Moscow, 1897.
Wood—*Trans. Ophth. Soc. U. K.*, XII.
Reich—*Klin. Monatsbl. f. Augenheilk.*, X.
Michaelson— *Centralbl. f. Augenheilk.*, XIII.

Coloboma of the optic nerve.

Bock—*Die Angeb. Col. des Aug.*, 1893.
Caspar—*Dissertation*, Bonn, 1887.
Coats—*Royal London Ophth. Hosp. Rep.*, Vol. XVII, Pt. II.
Cosmetattos—*Ann. d'Ocul.*, T. CXXXV, May, 1906.
Da Gamo Pinto—*Archiv f. Augenheilk.*, XIII.
Elschnig—*Archiv f. Ophth.*, LI; *Archiv f. Ophth.*, LVI, I.
Gilbert—*Archiv f. Ophth.*, LXV.
Görlitz—*Archiv f. Augenheilk.*, XXXV.
Ginsberg—*Centralbl. f. Augenheilk.*, XX.
Hess—*Archiv f. Ophth.*, XXXVIII.
Hird—*Ophth. Rev.*, Nov., 1912.
Kundrat—*Wiener Med. Blaetter*, 1886.
Liebreich—*Archiv f. Ophth.*, Vol. V., II.
Manz—*Archiv f. Augenheilk.*, XXIII, I.
Nieden—*Archiv f. Augenheilk.*, VIII.
Parsons—*Pathology*, Vol. III.
Parsons and Coats—*Brain*, pt. 114.
Van der Hoeve—*Archiv f. Augenheilk.*, LVII, 1.
Van Duyse—*Ann. D'Ocul.*, XCII; *Archiv. d'Ophtal.*, XI; *Encyc. Française*, 1905.
Von Ammon—*Archiv f. Ophth.*, Vol. IV, I.
Von Hippel—*Archiv f. Ophth.*, XLV; Graefe-Saemisch, 1900.
Zade—*Klin. Monatsbl. f. Augenheilk.*, XLV, No. 2.

Fuchs' coloboma.

Worton—*Ophthalmoscope*, Dec., 1911.
Coats—*Royal London Hosp. Rep.*, Vol. XVII, part II.
Schnabel—*Archiv f. Ophth.*, XX, 2; *Wiener Med. Blaetter*, 1884.
Elschnig—*Archiv f. Ophth.*, Bd. LI, heft. III; Bd. LVI, heft I.
Fuchs—*Archiv f. Ophth.*, XXVIII, I.
Liebreich—*Archiv f. Ophth.*, Vol. V, 2.
Wollenberg—*Charite Annalen*, XIV, 1889.
Vossius—*Klin. Monatsbl. f. Augenheilk.*, XXIII.
Harman—*Ophthalmoscope*, Aug., 1900.
Parsons—*Pathology*, Vol. III.
Van Duyse—*Encyc. Française*, II, 1905.
Symons—*Archiv f. Augenheilk.*, Bd., XLIV.
Szili—*Centralbl. f. prkt. Augenheilk.*, 1883.

Coloboma of the vitreous.

Bock—*Die Angeb. Col. des Augapfels*, 1893.
Hess—*Archiv f. Ophth.*, XXVIII, 3.
Manz—*Graefe-Saemisch*, 1st edition, 1876.

Etiology of colobomata.

Bach—*Archiv f. Ophth.*, XLV, I.
Becker—*Zur Anat. d. Gesunden u. Kranken Linse*, 1883.

Bock—*Die Angeb. Col. des Aug.*, Wien, 1893.
Chievitz—*Internat. Monatsch. f. Anat. u. Phys.*, IV, 1887; *Anat. Anzeiger*, II 1888, III 1889; *Archiv f. Mikr., Anat.*, 1889; *Archiv f. Anat. u. Phys.*, 1890.
Collins—*Trans. Ophth. Soc. U. K.*, Vol. XIII.
Coats—*Ophthalmoscope*, Oct., 1910.
Deutschmann—*Klin. Monatsbl. f. Augenheilk.*, XIX 1881.
Deyl—*Anat. Anzeiger.*, IX; *Centralbl. f. Augenheilk.*, XXI.
Ginsberg—*Centralbl. f. Augenheilk.*, XX.
Henckel—*Anat. Hefte.*, 1898.
Hess—*Archiv f. Ophth.*, XXXVIII—XXXIV, 3; *Archiv. f. Augenheilk.*, XLI.
Heyl—Internat. Cong., 1877; *Ann. d'Ocul.*, LXXVII.
Kämpffer—*Archiv f. Ophth.*, XLVIII, 3.
Lindsay Johnson—*Archiv f. Augenheilk.*, XXI.
Mannhardt—*Archiv f. Ophth.*, XLIII.
Manz—*Graefe-Saemisch*, 1876, 1st Ed.; Internat. Cong. Heidelberg, 1888.
Naumoff—*Archiv f. Ophth.*, XXXVI.
Pagenstecher—*Bericht der Ophth. Gesell.*, Heidelberg, 1911; *Ophthalmology*, Oct., 1911.
Parsons—*Pathology*, Vol. III.
Van Duyse—*Ann. d'Ocul.*, XX and XXI; *Encycl. Franc.*, II, 1905.
Pause—*Archiv f. Ophth.*, XXIV, 2.
Von Ammon—*Archiv f. Ophth.*, IV.—v. Ammon's *Zeit.*, I, 1831.
Rogman—*Archiv. d'Ophtal.*, XVII.
Von Hippel—*Graefe-Saemisch*, 1900; *Archiv f. Ophth.*, LV, 3.
Rumschewitsch—*Archiv f. Ophth.*, XXXVII, 4.
Vossius—*Archiv f. Ophth.*, XXIX.

Persistent hyaloid.

Müller—*Würzburger Verhandlungen*, 1856; *Archiv f. Ophth.*, II, 2.
Zehender—*Klin. Monatsbl. f. Augenheilk.*, I.
De Beck—Monograph, Oct., 1890.
Manz—*Graefe-Saemisch*, I, 1876.
De Wecker—*Klin. Monatsbl. f. Augenheilk.*, VII.
Galezowski—*Rec. d'Ophtal.*, 1882.
Otto—*Beiträge z. Augenheilk.*, V.
Oeller—*Dissertation*, Munich, 1878.
Bribach—*Archiv f. Ophth.*, LXXVI, I.
Remak—*Centralbl. f. Augenheilk.*, IX.
Loring—*Text Book*, Vol. 1.
Laurence—*Ophth. Rev.*, 1865.
Hasbrouck—*Jour. Ophth.*, I, 1889.
Unterharnscheidt—*Klin. Monatsbl. f. Augenheilk.*, XXX—XX.
Van Duyse—*Archiv. d'Ophtal.*, XI.
Stephenson—*Ophthalmoscope*, May, 1908.
Schaumberg—*Dissertation*, Marburg, 1882.
Schmidt-Rimpler—*Archiv f. Ophth.*, XXIII, 4.
Berger—*Klin. Monatsbl. f. Augenheilk.*, XXII.
Saemisch—*Klin. Monatsbl. f. Augenheilk.*, I—VII.
Gardiner—*Archiv. Ophth.*, Vol. IX.
Eversbusch—*Mitth. o. d. Klinik*, München, 1882.
Tangemann—*Archiv. Ophth.*, Vol. XVII.
Wolfrum—*Archiv f. Augenheilk.*, LXXIII.
Calderaro—*LaClin. Ocul.*, Apr., May, 1909.
Rockliffe—*Trans. Ophth. Soc. U. K.*, VII.
Randall—*Trans. Am. Ophth. Soc.*, 1888.
Dimmer—*Archiv f. Augenheilk.*, XIV.
Lang—*Trans. Ophth. Soc. U. K.*, V.
Brailey—*Royal London Ophth. Hosp. Rep.*, VIII.
Maisch—*Annals Ophth.*, July, 1908.
Nettleship—*Royal London Ophth. Hosp. Rep.*, VII.
Collins—*Royal London Ophth. Hosp. Rep.*, XIII.
Parsons—*Trans. Ophth. Soc. U. K.*, XXII—XXIII.

Marx—*Tydschr. v. Gen.*, Apr., 1908.
DeVries—*Tydschr. v. Gen.*, May, 1908.

Vitreous vessels.

Hirschberg—*Centralbl. f. Augenheilk.*, VII.
Parsons—*Pathology*, Vol. III.
Crampton—*Sec. Ophth. College Phys. and Surg.*, Phila., Jan., 1911.
Hansell—*Archiv. Ophth.*, May, 1909, p. 259.

Cilio-retinal vessels.

Lindsay Johnson—*Trans. Royal Soc. U. K.*, 1901, pp. 1.
Nettleship—*Trans. Ophth. Soc. U. K.*, Vol. XXV, pp. 338.
Jackson—*Trans. Am. Ophth. Soc.*, Vol. XII, 1911.
H. Müller—*Zeit. f. Wissensch Zool.*, VIII, 1856.
Nettleship—*Royal London Ophth. Hosp. Rep.*, IX, 1877.
Czermak—*Wien. Klin. Woch.*, 1888.
Leber—*Graefe-Saemisch*, I, 1876.
Elschnig—*Archiv f. Ophth.*, XLVIV, 1, 1897.
Parsons—*Pathology*, Vol. III, p. 865.
Elschnig—*Archiv f. Augenheilk.*, XVIII, 1888.
Salzmann—*Archiv f. Ophth.*, XXXIX, 4, 1893.
Donders—*Archiv f. Ophth.*, I, 1855.

Tortuosity of vessels.

Benson, Nettleship—*Trans. Ophth. Soc. U. K.*, II.
Lawford—*Trans. Ophth. Soc. U. K.*, XV.
Werner—*Trans. Ophth. Soc., U. K.*, X.
Mackenzie—*Trans. Ophth. Soc. U. K*, III and IV
Horrocks—*Trans. Ophth. Soc. U. K.*, III.

Choroido-vaginal veins.

Shoute—*Archiv f. Ophth.*, XLVI, 2.
Coats—*Ophth. Review*, XXV.
Elschnig—*Archiv f. Augenheilk.*, XVIII and XLIV.
Parsons—*Pathology*, Vol. III.
Van Geuns—*Archiv f. Augenheilk.*, XLVIII.
Breuil—*L'Ophtal. Provinciale*, IV, Nov., 1907.
Van Der Hoeve—*Archiv f. Ophth.*, July, 1907.

Medullated nerve fibers.

J. F. Shoemaker—*Trans. Ophth. Sec. St. Louis Med. Soc.*, Feb., 1908.
Schreiber—Rep. 34th Meeting Op. Soc. at Heidelberg, Aug., 1907.
Mayerweg—*Archiv f. Augenheilk.*, XLVI.
Fuchs—*Text Book*—4th Am. Ed.

Detachment of retina.

Fernandez—*Archiv. of Ophth.*, Vol. XXXIV, No. 4.

Bifurcation of veins.

Bahn—*Ophthalmology*, VI. 4.
Frost—*Trans. Ophth. Soc. U. K.*, IX.
Werner—*Trans. Ophth. Soc. U. K.*, X.
Stephenson—*Trans. Ophth. Soc. U. K.*, XI.

Arterio-venous anastomosis.

Marcus Gunn—*Trans. Ophth. Soc. U. K.*, IV.

Absence of retinal vessels.

Von Graefe—*Archiv f. Ophth.*, Vol. I., I.
Retze—*Beiträge zur Augenheilk.*, XLVII.

Optico-ciliary vessels.

Braune—*Klin. Monats. f. Augenheilk.*, XLIII.
Shoemaker—*Annals Ophth.*, Apr., 1909.
Benson—*Trans. Ophth. Soc. U. K.*, 1883.
Elschnig—*Archiv f. Augenheilk.*, XVIII and XLIV.
Bloch—*Klin. Monats. f. Augenheilk.*, XLIV.
Höeg—*Archiv f. Ophth.*, LV, 2.

Aplasia of the optic nerve.

Dareste—*Sur la Production Artif. des Monstruosités Paris*, 1877.
Lebedeff—Virchow's *Archiv*, XXVI.
Manz—Virchow's *Archiv*, LI.
Mayou—*Trans. Ophth. Soc. U. K.*, XXIV.
Meissner—*Archiv f. Ophth.*, Vol. 79, part 2.
Perls—*Lehrbuch d. Allgem. Path.*, Stuttgart, 1894.
Petren—Virchow's *Archiv*, CLI, 1898.
V. Wahl—*Dissertation, Dorpat*, 1839.

Hole in the disc.

Marcus Gunn—*Trans. Ophth. Soc. U. K.*, Vol. VI, p. 374.
Frost—*The Fundus Oculi*, 1896.
Thompson and Ballantyne—*Trans. Ophth. Soc. U. K.*, XXIII, 277.
Reis—*Zeitsch. f. Augenheilk.*, June, 1908.
Stood—*Klin. Monatsbl. f. Augenheilk.*, 1884, p. 285.
Wiethe—*Archiv f. Augenheilk.*, Bd. II, 1882.
Lichtenstein—*Centralbl. f. Prkt. Augenheilk.*, 1907.
Coats—*Royal London Ophth. Hosp. Rep.*, Jan., 1908.
Stephenson—*Ophthalmoscope*, Feb., 1909.
Carr—*Ophthalmoscope*, Nov., 1909.
James—*Ophthalmic Review*, Feb., 1913.

Large disc.

Hack—*Archiv f. Augenheilk.*, June, 1909.

Lachrymal apparatus.

Kuesel—*Zeitsch. f. Augenheilk.*, XVI.
Tooke—*Ophthalmology*, Apr., 1910.
Born—*Morphol. Jahrbücher*, Bd. II and V.
Legal—*Morphol. Jahrbücher*, Bd. VIII.
Kölliker—1860 Entwick. des Mensch und der H. Thieren.
Ewetsky—*Archiv f. Augenheilk.*, Bd. VII.
Cosmettatos—*Archiv f. Augenheilk.*, Bd., LV.
Matys—*Zeitsch. f. Augenheilk.*, Bd. XIV, 1905.
Manz—*Graefe-Saemisch* Bd. II, Kap. VI, 2nd Ed.
Galezowski—*Traité des Mal. des Yeux*, 1872.
Talko—*Klin. Monatsbl. f. Augenheilk.*, Bd. X, 1872.
Vossius—*Beiträge f. Augenheilk.*, Heft. II.
Graefe—*Archiv f. Ophth.*, Bd. 1, hft. II, 1854.
Weber—*Archiv f. Ophth.*. Bd. VII, Hft. I.
Zehender—*Klin. Monatsbl. f. Augenheilk.*, 1863.
Steffan—*Klin. Monatsbl. f. Augenheilk.*, IV.
Fitzgerald—*Royal London Ophth. Hosp. Rep.*, VIII.
Streatfeild—*Lancet*, 1882.
Ryder—Norris and Oliver, Vol. 1.
Halben—*Archiv f. Ophth.*, Bd. LVII.
Bochdalek—*Prager Vierteljahreschrift*, 1866.
Loehlein—*Bericht der Oph. Gesellsch.*, 1908.
Tyson—*Archiv. of Ophth.*, July, 1908.
Manz—*Graefe-Saemisch*, II, 113.

De Wecker—*Traité Complet d'Ophtal.*, IV.
Hartridge—*Trans. Ophth. Soc. U. K.*, XII.
Wood—*Archiv. of Ophth.*, XXIII, 1894.
Agnew—*Trans. Am. Ophth. Soc.*, 1874.
Dunn—*Archiv. of Ophth.*, XXIV, 1895.
Roy—*Am. Jour. Ophth.*, XII, 1895.
Barnes—*Trans. State Med. Soc. Wis.*, XXXII, 1898.
Terlinck—*Zeitsch. f. Augenheilk.*, XXIV, 6.
Mackenzie—*Diseases of the Eye*, 1830.
Steinheim—*Klin. Monatsbl. f. Augenheilk.*, XIII, 1875.
Wernecke—*Klin. Monatsbl. f. Augenheilk.*, XLVII, 1.
Nance—*Jour. Ophth. and Oto-Laryng.*, May, 1907.
Zehender—*Klin. Monatsbl. f. Augenheilk.*, 1883.
Lafite Dupont—*Societe d'Anat. et de Phys. de Bordeaux*, 1895.
Magnus—*Klin. Monatsbl. f. Augenheilk.*, XIII, 1875.
Emmert—*Archiv f. Augenheilk.*, V, 1875.
Parsons—*Pathology*, Vol. III.
Von Hippel—*Graefe-Saemisch*, 1900.
Luedde—*Annals Ophth.*, July, 1912.
Barfurth—*Sitzungsbericht d Nat. Gesell. z. Rostock*, 1899.
Zabel—*Dissertation*, Rostock, 1900.
Van Duyse—*Encyc. Française*, II, 1905.
Noyes—*Diseases of the Eye*, 1890.
Mauthuer—*Wien. Med. Presse*, Bd. XIX, 1878.
Brière—*Bull. et Mem. Soc. de Chir. de Paris*, 1876, Vol. II.
Snell—*Ophth. Review*, Vol. I, p. 207.
Jones—*Ophthalmology*, Oct., 1910.
Beyer, Otto, Travers—Graefe-Saemisch, I, 1876.
Augieras—*L'Opht. Provinciale*, 1906.
Purtscher—*Centralbl. f. Pkt. Augenheilk.*, 1910.
Cassimatis—*La Clin. Ophtal.*, Vol. XVII, 1911.
Mayou—*Royal London Ophth. Hosp. Rep.*, Jan., 1908.
Ollendorf—*Die Ophth. Klinik*, Jan., 1907.
* Hirsch—*Archiv f. Augenheilk.*, 1902.
Fejer—*Archiv f. Augenheilk.*, LVII, I.
Jackson—*Ophth. Record*, Sept., 1907.
Selenkoff—Virchow's *Archiv*, 1884.
Landow—*Deutsche Zeit. f. Chir.*, XXX, 1890.
Kraske—*Archiv. f. Klin. Chir.*, XX, 1876.
Van Duyse and Rutten—*Archiv. d'Ophtal.*, XVII, 1897.
Vlacovich—Nagel's *Jahresbericht*, 1871.

* Peters—Quoted by Hirsch.

Pigmentation of the disc.

Liebreich's Atlas 1870.
Hirschberg—*Centralbl. f. Augenheilk.*, VI.
Schleich—*Klin. Monatsbl. f. Augenheilk.*, XXIII.
Pick—*Archiv f. Augenheilk.*, XLI.
V. Foerster—*Klin. Monatsbl. f. Augenheilk.*, XIX.
Fejer—*Archiv f. Augenheilk.*, Oct., 1907.
Coats—*Royal London Ophth. Hosp. Rep.*, Jan., 1908.
Dyckmeester—*Archiv f. Augenheilk.*, Vol. XLVIII, 1903.
Leber—*Bericht d. Ophth. Gesellsch.*, 1898.
Westhoff—*Centralbl. f. Augenheilk.*, XXII.
Parsons—Internat. Cong., Lucerne, 1904.

Melanosis oculi.

Kraemer—*Centralbl. f. Augenheilk.*, May, 1906.
Thompson and Ballantyne—*Trans. Ophth. Soc. U. K.*, XXIII, 1903.
Stock—*Klin. Monatsbl. f. Augenheilk.*, XXXIX 2 s., 770.

Krukenberg—*Klin. Monatsbl. f. Augenheilk*, XXXVII, pp. 254; *Klin. Monatsbl. f. Augenheilk*, XXXVII, pp. 478.
Polte—*Archiv f. Augenheilk*, XLVIII, 1903.
Wintersteiner—*Wien. Klin. Woch.*, VI; *Archiv f. Ophth.*, LVII.
Van Duyse—*Annals d'Ocul*, XCV.
Gesang—*Beiträge z. Augenheilk.*, 1904.
Von Hippel—*Graefe-Saemisch Handb.*, 1900; *Archiv. f. Ophth.*, LII, p. 473.
Schweigger—*Archiv f. Augenheilk.*, XVII, s. 403.
Parsons—*Pathology*, Vol., III.
Holloway—*Annals of Ophth.*, Oct. 1910.
Tweedie—*Ophth. Record*, March, 1911.
Von Ammon—*Darstell. d. Krankh. u. Bildungsf. d. Menschl. Auges.*, 1841, part III.
Buchanan—*Trans. Ophth. Soc. U. K.*, Vol., XXIII.
Eddowes—*Brit. Med. Jour.*, 1910, Vol. II.
Harman—*Ophthalmoscope*, 1910, Vol. VIII.
Hay—*Ophthalmoscope*, 1907, Vol. V.
Peters—*Klin. Monatsbl. f. Augenheilk.*, 1908, s. 130.
Stephenson—*Ophthalmoscope*, 1910, Vol. VIII.
Roll—*Trans. Ophth. Soc. U. K.*, Vol. XXVIII, fasc. 3.
Rolleston—*Ophthalmoscope*, May, 1911.
Adair-Dighton—*Ophthalmoscope*, April, 1912.

Heterochromia iridis.

Butler—*Ophthalmoscope*, July, 1911.
Beaumont—*Ophthalmoscope*, Sept., 1911.
Fuchs—*Zeitsch. f. Augenheilk.*, 1906, Hft. III. *Text Book*, 4th Am. Edition.
Galezowski—*Recucil d'Ophtal.*, June, 1910, and March, 1911.
Hutchinson—*Royal London Ophth. Hosp. Rep.*, 1869.
Lutz—*Deutsche Med. Woch.*, Bd. XXIV, 1910.
Malgat—*Recueil d'Ophtal.*, 1889-1895 and 1899.
Marcus Gunn—*Ophth. Review*, 1889.
Sym—*Ophth. Review*, 1889.

Albinism.

Blumenbach—De Oculis leucæthiopum et iridis motu, Göttingen, 1786.—*Handbuch d. vergleich. Anat.*, 1824.
Butler—*Ophthalmoscope*, Aug., 1908.
Lagleyze—*Archiv. d'Ophtal.*, May, June, July, 1907.
Müller—*Beiträge z. Augen.*, heft VIII, 1892.
Rawitz—*Archiv. d'Ophtal.*, T. XXVII.
Sautter—*Annals of Ophth.*, April, 1910.
Seefelder—*Graefe's Archiv.*, 70-1.
Thompson—*Ophthalmoscope*, Dec., 1910.
Wafer—*In Mansfeld Ueber das Wesen der Leucopathie*, Brauschweig, 1882.
Buzzi—*In Seiler, Beobachtungen Ursprüngl. Bildungsfehler*, Dresden, 1833.
Darwin—*Origin of Species*, 6th edition.
Fuchs—*Text Book* (4th American edition).
Mayerhausen—*Klin. Monatsbl. f. Augenheilk.*, XX, 1882.

Congenital tumors.

Parsons—*Pathology*, Vol. I, pp. 132.
Ryba—Prager's *Vierteljahreschrift*, III, 1853.
Nobbe—*Archiv f. Ophth.*, XLIV, 3.
Talko—*Klin. Monatsbl. f. Augenheilk.*, 1888.
Rieke—*Archiv f. Augenheilk.*, XXII.
Gallenga—*Annales d'Ocul.*, XCIV.
Cohn—*Dissertation*, Heidelberg, 1897.
Wagenmann—*Archiv f. Ophth.*, XXXV.
Von Hippel—*Graefe-Saemisch*, 1900.
Bernheimer—*Archiv f. Augenheilk.*, XVIII.

Osburn—*St. Thos. Hosp. Rep.*, VI.
Levitt—*N. Y. Med. Jour.*, July, 1908.
Trousseau—*Annales d'Ocul.*, CXXXVII.
Caldedaro—*La Clin. Ocul.*. Jan., 1908.
Sgrosso—*Lav. della Clin. Ocul. di Napoli*, IV, p. 323.
Burgeois—*L'Ophtal. Provin.*, T. II, Feb., 1906.

Fibroma.

Weinstein—*Klin. Monatsbl. f. Augenheilk.*, Nov., 1909.
Cosmettatos—*Annales d'Ocul.*, April, 1911.
Mann—*Jour. of Ophth. and Oto-Laryng*, Apr., 1909.

Teratoma.

Mizou—*Archiv f. Augenheilk.*, LXV.
Coulter and Coats—*Royal London Ophth. Hosp. Rep.*, Jan., 1910.
Elliott and Ingraham—*Ophthalmoscope*, Dec., 1910.

Chondroma.

Reuchlin—*Klin. Monatsbl. f. Augenheilk.*, XLIV, II.

Congenital cysts of the iris.

V. Rosenweig—*Beiträge f. Augenheilk.*, XVI.
Lagrange—*Traité des Tumeurs de L'oeil*, I, Paris, 1901.
Gallemaerts—*Archiv. d'Ophtal.*, 1907.
Badal—*Archiv. d'Ophtal., June*, 1911.

Congenital blindness occurs as a result of defects in development, or of intra-uterine inflammation. Among these anomalies are: corneal and lens opacities, closure of the pupil, atrophy or arrested development of the intraocular membranes or of the optic nerve, enlargement or reduction in size of the eyeball, or its complete absence—anophthalmos.

Those patients with congenital cataract, who in later years have been relieved by operation, have been well studied, especially as regards the facts concerned with their learning to see. See **Congenital anomalies of the eye.**

Congenital defects. See **Congenital anomalies of the eye.**

Congenital malformations of the eye. See **Congenital anomalies of the eye.**

Congestion hyperemia. This term is applied to methods by which the blood supply of all parts is increased, generally by some mechanical apparatus or by some constriction of the parts. For example, Renner believes that this treatment is applicable only to persons up to forty years of age, in whom disease of the heart and circulatory system can be excluded. Cases where there is a deep-seated inflammation of the eye (iritis, iridocyclitis, irido-choroiditis acuta) must be excluded. The treatment was used by Renner (*Wien. Med. Blätter*, Feb. 1, 1906) in five cases of parenchymatous keratitis, in phlyctenular conjunc-

tivitis and in ulcus corneæ. In each case the duration of the treatment was six to twelve hours daily during two to four weeks. In one case of parenchymatous keratitis after four weeks of treatment vision improved from 2/200 to 5/10. In none of the cases was any injurious effect of the treatment noticeable.

In order to localize the constricting action to the eye, Hesse (*Ophthalmic Record*, January, 1906) devised an apparatus similar to the artificial leech. The cup fitting to the ocular region is, by means of a tube, connected with a balloon, by which suction is produced. Hesse saw good results from its application in serpent ulcer, the case of which is reported in detail. The suction hyperemia was applied for from five to thirty minutes twice a day, and the ulcer healed in two weeks.

There are in the market several convenient and effective instruments for the production of ocular hyperemia. Two of these, Pynchon's pump and the Victor suction apparatus, have been used with much satisfaction by the Editor and his associates.

Congestion papilla. One of the terms sometimes applied to choked disk.

Congiuntiva. (It.) Conjunctiva.

Congiuntiva cuticulare. (It.) Cuticular conjunctiva.

Congiuntiva del bulbo dell'occhio. (It.) Bulbar conjunctiva.

Congiuntiva del tarso. (It.) Conjunctiva tarsi.

Congiuntiva follicolare. (It.) Granular conjunctiva.

Congiuntiva granulosa. (It.) Granular conjunctiva.

Congiuntivite. (It.) Conjunctivitis.

Congiuntivite autumnale. (It.) Autumnal conjunctivitis.

Congiuntivite blenorroica dei neonati. (It.) Acute blennorrhea of the new-born.

Congiuntivite crupale. (It.) Croupous conjunctivitis.

Congiuntivite da acne. (It.) Acne conjunctivitis.

Congiuntivite difterica. (It.) Diphtheritic conjunctivitis.

Congiuntivite esantematica. (It.) Exanthematous conjunctivitis.

Congiuntivite flittenulare. CONGIUNTIVITE FLITTENOIDE. (It.) Phlyctenular conjunctivitis.

Congiuntivite flittenulare semplice. (It.) Simple form of phlyctenular conjunctivitis.

Congiuntivite gropposa. (It.) Croupous conjunctivitis.

Congiuntivite purolenta. (It.) Purulent conjunctivitis.

Conglomerate tubercle. A term applied to masses of tubercular deposit as opposed to the miliary variety. For example, see an account given

of this affection—of the choroid—by E. Fuchs (*Beiträge zur Augenheilk.*, p. 556, 1911). See **Choroiditis, Tubercular.**

Congo-Augenkrankheit. (G.) Congo disease of the eyes.

Congo-disease of the eyes. In the Congo there occurs both in white men and in negroes a diffuse chorio-retinitis with involvement of the vitreous humor. As a rule, the disease is unilateral, but often one eye is affected after the other. The iris and ciliary body usually escape but they also may be involved, and in this event the infection may last for months; otherwise it disappears spontaneously within a week or two. The treatment, especially if the uveal tract be involved, is the local use of hot fomentations, leeches and atropia; the general treatment is chiefly sweats.

Conia. (L.) Coniine.

Conical cornea. Keratoconus. Hyperkeratosis. Staphyloma pellucidum conicum. Conical hydrophthalmia. Conical-formed cornea. This is an anomalous condition in which the central part of the cornea loses its normal convexity and assumes the form of cone. The change is unaccompanied by inflammatory manifestations and the corneal substance usually retains its normal transparency. In some cases at or very near the apex a small opacity may be determined.

The apex of the cone, as a rule, is not central, but usually below the center, its position being influenced, according to Noyes (*Diseases of the Eye*, New York, 1890, p. 387) by pressure of the border of the upper lid. Females are more susceptible to the disease, and both eyes are usually affected. The deformity is seldom recognized before the twelfth or fourteenth year of life. At times, the deformity assumes an extraordinary size. Noyes (*Journal Am. Med. Assoc.*, Sept. 10, 1892, p. 314) reports having observed a conical cornea three-quarters of an inch long.

Well-marked cases of conical cornea, when viewed in profile, are easy of recognition. All cases, even where the conicity is difficult of determination, present a peculiar sparkling, diamond-like brilliancy, likened by Pickford (*Dublin Jour. of Med. Science*, 24, 1843, p. 355) to a "dew-drop, or a piece of solid crystal, embedded in the corneal center." When light is thrown upon the cornea by the ophthalmoscopic or retinoscopic mirror, the reflex is observed to be smaller at the center, and a dark circular shadow may be observed between the limbus and the center.

The image of the fundus is distorted. The corneal deformity may be demonstrated by Placido's disc or the ophthalmometer of Javal. The excessive thinness of the corneal apex may be demonstrated by touching it with a probe.

Demours (*Traité des Maladies des Yeux*, Vol. 1, p. 316, Paris, 1818) observed the condition as early as 1747. It was described by Scarpa (*Traité des Maladies des Yeux*, Vol. 11, p. 179. Paris, 1802).

The precise mode of production or development of the disease has not been definitely determined. That conical cornea is a congenital deformity, like high degrees of myopia and keratoglobus, differing from the latter in that the internal ocular structures show no implication even during the period of progression, is the belief of Sattler (*Am. Jour. of Ophthal.*, Sept., 1898, p. 257).

Conical Cornea.

Swanzy (*Diseases of the Eye,* 9th Ed., p. 261, London, 1907) says the "change is due to gradual and slowly advancing atrophic process in the cornea at or near its center, in consequence of which the normal intraocular tension acts on it so as to distort it into conical form. It is due to congenital weakness at the center of the cornea or by a chronic degeneration of the membrane of Descemet."

Salzmann (v. Graefe's *Archiv f. Ophthalmologie,* Vol. 67. 1, 1908; abstracted by Ballantyne, *Ophth. Review,* May, 1908) has made a histological examination of an eye affected by this lesion. The microscopical examination showed thinning of Bowman's membrane and many gaps in its continuity. "These gaps are filled with a peculiar connective-tissue, distinguishable from the corneal stroma, and containing elastoid fibres like those found in pinguecula. The same tissue in places passes before and behind the intervening portions of Bowman's membrane so as partly or completely to embrace them. The deeper layers of the corneal stroma in the region corresponding to

the summit of the conus (and the thinnest part of the cornea) present some tendency to splitting, with the formation of lacunæ longer than those in the normal stroma. Irregularity of nuclear division is also found in this part of the cornea. In the region of the ectasia, and practically at the centre of the cornea, there is a considerable gap in Descemet's membrane. The free edges are elevated from the corneal stroma, and the endothelial cells have grown round on to their anterior surface. These cells show granular and other changes.

"The peripheral parts of the cornea have the normal thickness, and thus contrast with the ectasia in which the thickness of the cornea is reduced by about a half. In the temporal half of the cornea there is a defect of Bowman's membrane, reaching from the margin of the conical part to the edge of the cornea. In this area it is replaced by a fibro-cellular tissue somewhat resembling an avascular pannus. The epithelium rests upon a fine homogeneous membrane which gives the coloring reactions of fibrillary connective-tissue. The posterior surface of Descemet's membrane is covered with a thin layer of connective-tissue, and, towards the margin of the cornea, between this and the endothelium, there lies a second homogeneous glassy layer. Other changes in the eyeball, having no direct relation to the corneal anomaly, are classified as anomalies of development and acquired pathological changes. The trabeculæ of the ligamentum pectinatum are thicker and the spaces narrower than the normal. The sclera reaches its maximum thickness at the equator, and is thicker on the temporal side than on the nasal. The ciliary muscle is of the myopic type. Granules like those found on the cells on Descemet's membrane are also present in the non-pigmented layer of the pars ciliaris retinæ.

"The lens is cataractous and shrunken. The anterior capsule is wrinkled, and there is a thick anterior capsular cataract.

"The optic nerve is almost totally atrophic. In the temporal side of its dural sheath runs a large artery, the significance of which is discussed in another part of the paper. The optic nerve entrance shows the characters of a peripapillary atrophy of the choroid. The retina also shows atrophic changes, but the macula is well preserved.

"In the peripheral parts of the retina there is a peculiar growth of the supporting tissue of the retina into the vitreous."

Salzmann recognizes two types of keratoconus—(1) ectasia confined to the optical zone, no ectasia of periphery of cornea, a shallow furrow at the junction of the cone and the normal cornea: this includes his own case and those of Bowman, Hulke and Jaeger; (2) gradually diminishing thickness of cornea from periphery towards the centre, hyperbolic curvature of cornea as a whole (cases of Rampoldi and

Uhthoff). The condition in the second group corresponds with the staphyloma posticum of Scarpa, while the first resembles the staphyloma posticum verum.

Discussing the nature of the cicatricial tissue which fills the gaps in Bowman's membrane, he identifies it with the tissue which fills similar gaps in cases of hydrophthalmos among others. He agrees with Elschnig that it is a regenerated corneal tissue, in the sense that it arises from the fixed cells of the corneal stroma, and that it is formed to fill up the gaps created in Bowman's membrane as a result of the stretching. But it differs widely from normal corneal tissue, and clinically gives rise to the delicate macular, striate or branching opacities which gradually make their appearance in the apex of the higher degrees of keratoconus.

The gap in Descemet's membrane is also to be referred to the stretching of the ectatic portion. He agrees with Axenfeld that the rupture of Descemet's membrane is not a cause of the keratoconus, nor does he find in his case anything to support Elschnig's view, that the cause lies in some chronic affection of Descemet's membrane and its endothelium.

Assuming that the ectasia can only be due, either to excessive intraocular tension, or to diminished resistance of the cornea, he rejects the former and accepts the latter.

An early ulceration might be suggested as a cause of diminished local resistance, but there is no evidence to support this, while the other etiological factors which have been suggested such as injury, errors of refraction, anemia, pregnancy, etc., may all be absent. He therefore falls back on congenital causes. The fact that keratoconus may be a family affection, and that it may be associated with congenital defects, is suggestive of developmental error. Tweedy's theory assumes a developmental failure either in the epiblast at the time of separation of the lens or in the mesoblast at the time of formation of the corneal stroma, but if that is correct how does the defect remain latent up till about the period of puberty?

Salzmann suggests that although the cornea apparently reaches the limit of its growth in the first twelve months following birth, there will be for some time thereafter a progressive strengthening of the fibrillary structure and diminution of the cells, leading to an increase in the rigidity of the cornea. Should this process show a partial failure at the centre of the cornea, we have the condition necessary for the production of keratoconus.

The early attempts to remedy the distressing symptoms of conical cornea by surgical intervention were directed towards the alteration

of structure behind the cornea rather than to change the nature of the deformity itself. In 1817, Sir William Adams (*Jour. of Science and Art.* (Am. Ed.), Vol. 2, 1817, p. 402.) advocated the "breaking up of the crystalline lens in order that the rays of light might fall upon the retina and not be brought by the increased refractive power of the cornea and lens to a point far short of the sentient apparatus of the organ of vision." This procedure undoubtedly consisted of the so-called "needling operation," and appears to be the first surgical procedure employed in conical cornea.

Demours (*Traité des Maladies des Yeux,* Vol. 1, p. 316, Paris, 1818), about that time, declared that "lorsque je suis consulté pour cette lesion, je conseille de n'y rien faire de particulier," and his suggestion was the probably accepted dictum to the time that Sir William proposed his operation. Adams' procedure evidently had few supporters. In 1840, Tyrrell (*Practical Work on Diseases of the Eye and Their Treatment,* p. 277, London, 1840) proposed "altering the position of the pupil and removing it from beneath the center of the cornea, or that part which has its figure most changed, to near the margin where the least change has occurred; the error in the refraction is consequently much lessened, and vision becomes more perfect and the focus is lengthened." Shortly after the publication of Tyrrell's work, Middlemore (*Lond. Med. Gaz.,* Vol. 1, N. S., 1842-4, p. 544) made the claim that it was he and not Mr. Tyrrell who first made the suggestion of "altering the position of the pupil" in conical cornea, and quotes the following extract from his book published nine years before: (*Treatise on Diseases of the Eye and Its Appendages,* Vol. 1, p. 538, London, 1835.)

"Where the point of the central cornea has become opaque and vision is thereby rendered much more obscure than it would otherwise be, it has been proposed to make an artificial pupil near to the margin of the cornea which it is said will have two important advantages, namely, first, removing the pupil from the opaque part of the cornea; second, allowing the light to be transmitted through the least convex part of the membrane."

Tyrrell's or Middlemore's operation consisted in making an incision through the cornea at or near the limbus and allowing of prolapse of a portion of the iris. This procedure was later modified by the elder Critchett, (*Roy. Lond. Ophth. Hosp. Reports,* Vol. 11, 1859-60, p. 145) who amplified the operation by what he termed iridodesis (q. v.) or iridesis—ligature of the prolapsed portion of the iris. After the iris had prolapsed into the corneal wound, it was tied off with a single

knot; the strangulated portion sloughed and the remainder was included in the corneal cicatrix.

Bowman (*Roy. Lond. Ophth. Hosp. Reports,* Vol. II, 1859-60, p. 154) was prominent among those to adopt the operation of iridodesis. Having observed that the vision of patients with conical corneæ was often improved by the use of the stenopaic slit, he attempted permanently to supply such an opening by converting the pupil into a transverse slit by means of an iridodesis, done twice in each eye. The frequent, severe and dangerous attacks of iritis and cyclitis consequent upon the operation, however, caused the procedure to be abandoned.

In 1847, Dix, (*Boston Med. and Surg. Jour.,* May 12, 1847, p. 289) of Boston, revived the operation of puncturing the cornea at its periphery, which had been performed as far back as 1811. (*Edinburgh Med. and Surg. Jour.,* Jan. 11, 1811, p. 6.) The punctures were made daily, or oftener, with a cataract needle about 1/16 of an inch broad, and a compress bandage was applied. By this method it was hoped to permanently reduce the conicity of the cornea. Dix reports several cases in which there was marked improvement in vision. In one patient 144 corneal punctures were made during a period of 18 months.

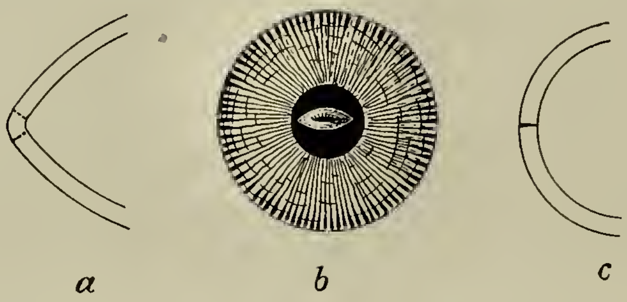
A. von Graefe (*Archiv. f. Ophth.,* Vol XII, 1866) in 1886 proposed, as a marked advance in the surgery of conical cornea, the removal of the epithelial layer of the apex of the cone and the application of caustic. The epithelial coat was shaved off, without entering the anterior chamber; the fragment of a stick of nitrate of silver was later applied, and finally the floor of the resulting ulcer was punctured. The object of the procedure was to bring about gradual flattening of the cornea by cicatricial contraction. Severe intraocular inflammatory manifestations frequently followed the procedure and necessitated its abandonment.

In 1869, Bowman devised a trephine by which he excised a disc of corneal tissue at or near the apex of the cone. The instrument, while ingeniously devised, did not prove of great practical value on account of the extreme thinness of the cornea, and in a considerable proportion of cases the degree of contraction resultant from its use was inadequate to relieve the deformity.

Bader (*Lancet,* 1872, p. 73) reported a number of cases in which he performed excision of the apex of the cone. An elliptical piece was removed from the most prominent part of the cone with a linear knife in such a manner that the edges of the opening in the cornea approximate and completely close the artificial cleft. The chief and most serious complication of the operation was iris prolapse, with its

attendant unfortunate sequelæ. To obviate this danger and to assist in early closure of the wound Badal (*Archiv. d'Ophtal.*, Aug., 1910, p. 433) passed horse-hair sutures vertically through the cornea previous to removing the apex, and after abscission tied them over the opposed edges of the gap.

Critchett (*Practitioner,* 1895, p. 426) removed a small elliptical piece of the cone at the apex, making the upper portion of the section with a very narrow Graefe knife, completing it with scissors; the fragments being removed with blunt forceps. Bader's operation, even with its modified technic, was more or less hazardous on account of the violent reaction, probability of infection, and formation of anterior synechia, and at the present time has not been enthusiastically adopted.



Critchett's Operation for Conical Cornea.
(*a* and *b*) Incisions through apex of cone to remove elliptical piece of tissue, (*c*) Edges of wound in close apposition.

Excision of a segment of the cornea from the base of the cone, as performed by Q. Roosbrock, and multiple puncturings of the apex of the cone with a fine cataract needle, as mentioned by Swanzy and Werner, are other methods which have been employed from time to time. Little benefit seems to have accrued from the former of these procedures, although the latter method has some firm advocates. The punctures are made two or three times at each sitting, and may be repeated at intervals of a fortnight or more. A firm bandage is afterwards applied. Flattening of the cone is brought about by the formation of a network of cicatricial tissue without the production of much corneal opacity.

Inasmuch as the antero-posterior axis of the eyeball is increased in conical cornea, there results a decided myopia. The conicity of the cornea is also responsible for high degrees of astigmatism; consequently a careful correction of the refractive error is imperative. This should be done at rather frequent intervals as the progress of the disease is responsible for repeated changes. Much care and practice are required in working out the refraction of these cases. A prolonged use of eserine with a pressure bandage has been said to benefit the condition.

and as mentioned, the stenopaic disc at times improves vision. The use of astringent collyria has been from time to time recommended, as has the administration of iron and the iodin derivatives.

Indications for surgical intervention in keratoconus. It is only in the slight or moderate cases that much benefit is to be expected from non-surgical procedures. In the more advanced cases the patient must submit to surgery if he is to expect much benefit. The degree of vision the patient possesses must be the index of operative interference. The writer's experience has led him to ally himself with the more conservative of his colleagues, and to recommend surgical intervention only in cases of an extreme character and in those patients whose vision has not been brought to a fair standard of usefulness by glasses. Just what that standard should be, must be

a *b*

Cauterization of Apex of Cone. Loss of tissue somewhat funnel-shaped with very small perforation.

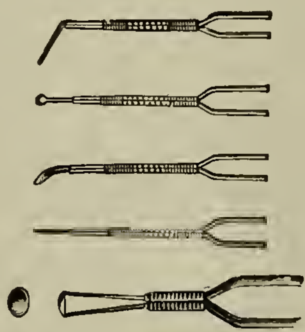
decided by the individual surgeon. Where there is useful vision in one eye and the other is markedly defective, the writer would not be inclined to operate. Should the vision of both eyes be less than 6/60, he would advise an operation.

In the surgery of conical cornea it must not be forgotten that the nutrition of the parts to be operated on is, to say the least, precarious, so that extreme delicacy, care and precision are imperatively essential. Galvano-cautery is by far the most common procedure and is unquestionably the most satisfactory from every standpoint, although excision of the apex is still sometimes employed. Repeated puncturing of the cornea at the vascular limbus, in conjunction with the use of pilocarpine and the compression bandage, is also recommended.

Technique of excision of the apex of the cone in keratoconus. The following is a description of Bader's operation as given by Higgins. (*Royal Lond. Oph. Hosp. Reports*, 1882, p. 316).

The pupil is widely dilated with atropin, and the usual preliminary aseptic precautions are attended to. The eye is anesthetized with cocain solution and the speculum is inserted. The eye is steadied

with fixation forceps in the hand of an assistant. The point of a thin Graefe knife is entered at the transverse meridian of the base of the cone and carried through the anterior chamber to a point opposite that of entrance. The knife is then brought outwards on the side of the cone. The small flap is picked up with iris forceps, and a second incision from without inwards completes the separation. A small opening tapering from both ends is the result, and if the incisions have been true the edges of the gap will exactly approximate. The iris in most instances will prolapse into the wound, in which case the healing will be slow and severe inflammation is likely to result.



Knapp's Cautery Points for Conical Cornea.

To avoid the latter contingency, Badal (*Archiv. d'Ophtalm.*, Aug. 21, 1901, p. 433) proposed a modification of the above procedure. Three horse-hair sutures were introduced vertically across the base of the cone, the central one of which was placed a little farther back than the other two. The elliptical flap was then removed as related above; the edges of the opening were approximated and the sutures tied. The author considers the use of horse-hair sutures as positively essential to the success of the operation, being easily and effectually sterilized. Every other material, including silk, has the disadvantage of inducing slight suppuration at the points of puncture.—(W. O. N.)

Charles A. Oliver has also discussed the treatment, both operative and non-operative, of this serious corneal anomaly in Wood's *System of Ophthalmic Operations*, Vol. 2, p. 961. He believes that although the *operative treatment* of this condition has been extensive it has, unfortunately, been without certain success in all cases. Among the procedures the creation of an artificial pupil by either an iridectomy or an iridodesis, iridotomy, and the production of cicatricial contraction of the conic apex by excision of circular areas and ellipses of tissue and cauterization, and removal of the crystalline lens may be

mentioned. In view of the present status of the study of the effeet of the internal secretions upon the body as given by Sajous of this city (see his many works upon the subjeet), and the evident inadequaey of radical measures, are we not more justified in Pickford's imperfect belief (Piekford—*On Conical Cornea,* 1844, p. 33), that conical eornea is dependent "upon faulty aetion, indueed by debility of the nerves of the eornea or its absorbent vessels, calling for an inereased deposit from the nutrient eapillaries, to repair the mischief arising from such faulty aetion"? He therefore submits "the probability, in the disease under eonsideration, of gastrie or intestinal disturbance or irritation, inducing, through the medium of the par vagum, sympathetic and ciliary nerves, faulty aetion of the absorbent and nutrient vessels of the cornea, the eombined effeet of whieh would be eonical cornea."

As early as 1810, Ware (*Observations on the Treatment of the Epiphora or Watery Eye,* 1818, p. 272) "repeatedly discharged the aqueous humor, and endeavored afterward, by moderate pressure, to prevent the return of the projeetion."

In order to neutralize the increased refraetive error produced by the eonicity of the cornea, Adams removed the erystalline lens (*Journal of Sciences and the Arts,* 1817, II, p. 403). He spoke of the ineffícieney of paraeentesis. Tyrrell (*Practical Work on the Diseases of the Eye,* 1840, Vol. I, p. 277) diseusses Adams' method in the following words: "It was thought that the removal of the crystalline lens, by getting rid of that convex and highly refraetive body, would afford better vision in sueh cases; but the praetiee has not, in the least degree, supported the theory; for it does no good." Pickford (*On Conical Cornea,* 1844, p. 12) also depreeates its usefulness. On the eontrary, Delafield, in his Amerieau edition of Travers' work (*A Synopsis of the Diseases of the Eye,* 1825, [1st Am. Ed.], pp. 311 and 312), gives an interesting aceount of a young man who applied at the New York Eye Infirmary "with both eorneæ eonical and a eataraet in one eye." The eataract was removed, and the patient eould see much more distinctly with the eye operated upon than with the other, assisted by a eoneave glass of any degree. In his comments upon this instance, he says, "The ease tends somewhat to prove the propriety of the plan recommended by some surgeons of removing the lens in eases of eonieal cornea, in order to compensate for the inereased refracting power of the cornea." Beard (*Ophthalmic Surgery,* 1910, p. 389) has had oeeasion "to eause removal of the lenses in a ease of high myopia and eonieity of the eornea by a series of discissions. The treatment eonsisted in incising the eapsule

through puncture at the base of the cornea—done with a Graefe knife, the use of atropine, and bandaging. The duration of treatment for each eye was about six months. There were three discissions in each, a good deal of reaction following the second and the third. The ultimate flattening of the cornea was truly remarkable. The best vision with glasses before the operations, etc., was 20/70, both eyes; the best after the year's treatment 20/30 + both. Here the annulment of the myopia, which had been 24 and 26 diopters, would account for most of the added sight, "I attributed (he says) much of it to the reduction of the cones."

Middlemore (*Treatise on the Diseases of the Eye and Its Appendages*, 1835, Vol. 1, p. 538) speaks of the value of the creation of an artificial pupil near to the margin of an opaque cone.

Flarer (Panas' *Traité des Maladies des Yeux,* 1894, p. 287) carried a filiform seton through the cone, hoping, by the gradual escape of the aqueous humor, to obtain its effacement.

Tyrrell (*Practical Work on the Diseases of the Eye,* 1840, Vol. 1, p. 278) made an artificial pupil in a place opposite that portion of the cornea which had undergone the least change. To accomplish this, he made a puncture through the outer and lower part of the cornea close to the junction of the sclerotic, by the aid of a broad needle. Through this opening a small blunt hook was introduced, and the pupillary edge of the iris was caught and carefully drawn through. As much as was necessary to make an artificial pupil was excised from the iris, close to the wound. He found that "in no instance has any evil followed beyond the slight degree of inflammation, necessary to repair the mischief, occasioned by the operation." While this may be so, and vision was bettered by exclusion of the peripherally placed rays of light, it must not be forgotten that in some cases there must be a marked increase in corneal astigmia. To obviate this, Bowman (*Treatise on the Diseases of the Eye* [4th Am. Ed.], 1883, pp. 250 and 251) had recourse to a double iridodesis: the incision for the second procedure being made in the sclerotic, some eight or ten days after the first, in order "to obtain the normal plane of the iris."

Favio (*Memoriale della medicina contemporanea,* 1839) resorted to the excision of a V-shaped flap at the summit of the cone without the application of sutures.

Bader (*Lancet,* Jan. 20, 1872, p. 73) states that he obtained favorable results from excising an elliptical piece of the apex of the cone. This he did by transfixing the apex of the cone with a von Graefe cataract knife and cutting from within outwards, thus producing a

small flap which was held in position by an iris forceps and was excised with a pair of scissors. No sutures were necessary. If the incision be made correctly, a lanceolate opening into the anterior chamber, the edges of which coapt so as to fill in the entire space, will be obtained. The pupil must be widely dilated before the operation is commenced and must be kept so, during the after-treatment. Care must be taken that too large a piece of corneal tissue is not removed. (He formerly "transferred the apex of the cone with a small curved needle carrying a suture" [*Report of the Fourth International Ophthalmological Congress,* 1872, p. 30]). The eye was bandaged.

Both Galezowski (*Bull. et mém. de la Soc. de Chir. de Paris,* 1886) and Despagnet (*Archives d'Ophtalmologie,* Jan.-Feb., 1891, p. 89) speak well of the Bader plan. In regard to this question, Noyes tells us (*Textbook on Diseases of the Eye,* 1894, p. 422) that it "has been proved that the effects of prolapse of the pupillary portion of the iris are far less important than of its peripheral parts. Moreover, as the prolapse takes place near the centre of the cornea the drag on the iris is a minimum. Care must, however, be taken (he warns us), to render the prolapse as small as possible, because if large, it may cause mischief." His own preference is "for excision of a small piece and uniting with sutures."

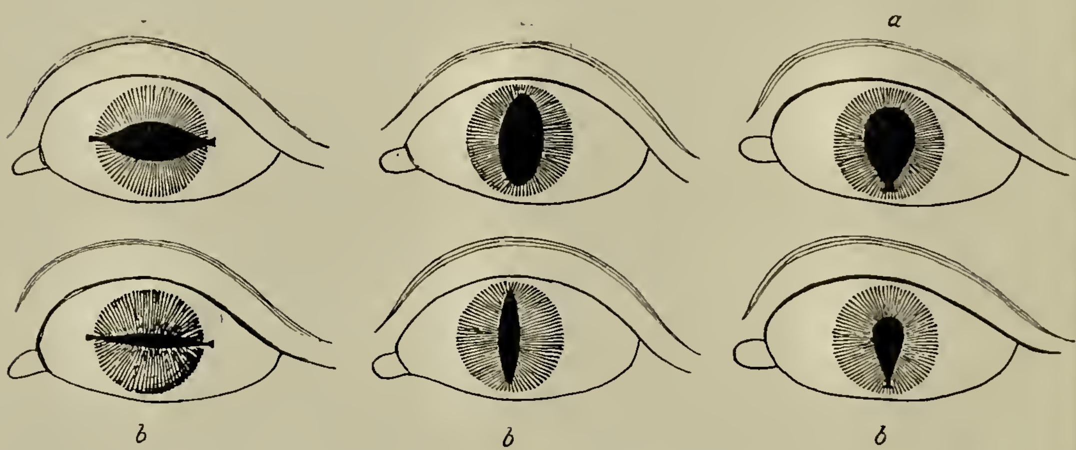
The chief disadvantage of this operation is (as Wells says [*Treatise on the Diseases of the Eye* (4th Am. Ed.), 1883, p. 252]) "that it often leaves a very extensive adhesion of the iris to the cicatrix, which may not only impair the acuity of vision, but prove of subsequent danger to the eye, in the same way as ordinary anterior synechia." The author of the operation, however, insisted that if the wounds were placed inside of the corneal limbus, there would not be any injurious after-effects from the procedure.

Badal (*Archives d'Ophtalmologie,* 21, p. 433) attempted to obtain a more rapid coaptation of the edges of the corneal wound by the use of horsehair sutures which had been set into position before excision of the flap, thus tending to prevent prolapse of the iris with the formation of anterior synechia. Noyes' (*Textbook on Diseases of the Eye,* 1894, p. 422) experience has been that excision of the apex by a Graefe knife and scissors and a drawing of the wound together by fine sutures, is a very delicate but feasible procedure. He states that the stitches must be the finest filaments obtained by unraveling twisted silk, and the curved needles both very small and sharp made expressly for the purpose. The whole corneal tissue is included and

the stitches must come out in two days. There need be no prolapse of iris, and the scar may be very small.

Silcock (*Trans. of the Ophth. Soc. of the U. K.*, 1893, p. 56) reports a case of conical cornea in which an elliptical wedge-shaped piece was removed from the apex of the cone by means of a von Graefe knife, the long axis of the wedge being placed at right angles to the meridian of highest refraction. Five and a half years after the operation, vision was brought to normal by aid of high minus cylinders with their axes placed obliquely. The original (possibly uncorrected) vision equaled one-tenth.

A case of successful excision of the apex of a conical cornea has been reported by Stauffer (*Ophthalmic Record,* May, 1906, p. 205).



Dilation and Contraction of Artificial Pupil in Conical Cornea.

For the better, the easier, and the more perfect excision of the elliptical piece of cornea, Critchett made use of an ingenious knife which consisted of two Sichel blades so arranged that they could be set at any required angle of excision. His ordinary operation of iridodesis was performed as follows: A small incision was made with the help of a broad needle through the marginal portion of the cornea at the point selected, and a noose of thread laid on the cornea surrounding the opening. A canula-forceps was passed through the loop and through the wound. The iris midway between the ciliary and pupillary margins was seized at about one-third way from the latter margin, and drawn out of the eye and secured by tying the loop (*Ophth. Hos. Rep. and Jour. of the Roy. Lon. Ophth. Hos.,* 1858. Vol. 1, pp. 220-225; Vol. 2, p. 145; and Vol. 4, p. 156).

To relieve the engagement of the iris and the corneal wound which had been so fatal to the ordinary "iridodesis" plan of Critchett, Bowman (*Ophth. Hos. Rep. and Jour. of the Roy. Lon. Ophth. Hos.,* 1859-1860, Vol. 2) employed a modification of the method for the

relief of the condition by the making of a double "iridodesis." He withdrew the pupillary border of the iris by means of fine hooks, converting the pupil into narrow slits which gave a marked betterment of visual result and seemingly had a beneficial influence upon the lessening of the corneal bulge. The shapes of the slit-like pupils can be better regulated by the double iridodesis plan made in opposite directions. He found that a vertically disposed pupil appeared to better advantage.

The accompanying diagrams exhibit the appearances of the pupils during dilation and contraction of the horizontal slit, the vertical one, and the balloon-shaped one.

Stellwag (*Lehrbuch der praktischen Augenheilkunde,* 1867, p. 259) states that the application of the ligature to the protruded portions of the iris, in either Critchett's first or second operation, is obtained only after the greatest difficulty. This complication the writer has seen while witnessing the procedure.

The immediate and the remote risks of both operations as regards inflammatory reaction of the iris and transference of inflammation to the opposite organ, however, have prevented their general employment.

Meyer's Needle for the Operation in Conical Cornea.

Von Graefe (*Archiv f. Ophth.* 12, p. 215) cauterized the conic apex which had been superficially scarified with a cataract knife. Care was taken that the membrane was not penetrated. After a period of a few days, the floor of the gap was lightly and repeatedly touched at several points with a crayon of mitigated nitrate of silver, followed by immediate neutralization. There was little or no reaction, the flattening of the resultant scar bettering the curvature of the cornea. In some cases the aqueous humor was evacuated by a paracentesis, made every few days for three or four times. A bandage was worn until the healing process had fairly well taken place. This, which led to the formation of a dense conical opacity, was followed, when necessary, by the making of a narrow optical iridectomy. Trélat (*Bull. et mém. de la Soc. de Chir. de Paris,* 1875) modified this plan by making the eschar at the periphery of the cornea, permitting the iridectomy to be better made at the opposite side of the membrane.

Meyer (*Practical Treatise on the Diseases of the Eye* [English Translation by A. Freeland Fergus], 1887, p. 149) prefers the method of von Graefe, except that he removes a portion of the cone of about

three millimeters in length just to the outside of its summit, taking care, as in the von Graefe operation, to avoid penetrating the anterior chamber. For this purpose, he has devised a special needle, the shape and size of which is shown herewith.

Having abandoned the Graefe method of the application of caustic to the abraded surface, by reason of prolonged irritation, Bowman, in 1869, employed drills for excision of a portion of the cone. They were constructed on the same principle as a Heurteloup artificial leech. The instruments varied in diameter, and were provided with a movable "stop" to regulate the depth of penetration (*Rep. of the Fourth Internat. Ophth. Congress,* 1873, p. 181). They were rotated by the finger and thumb.

Stephenson (*Ophthalmoscope,* June, 1910, p. 415) has modified this trephine to advantage by adopting the Argyll Robertson device of a handle, and having the instrument made from solid steel and drilled. "It carries a collar bearing pin, which fits into the slot of the pinion-wire handle, and thereby prevents the latter from rotating. The handle is fixed by a nut which screws on to the proximal end." He carried the trephined area merely down or just in front of the membrane of Descemet. The corneal flap was seized with a pair of fine forceps and dissected free with a broad needle. Later, the bulging floor of the abraded area was punctured at its centre (or a small portion of it excised), thus allowing temporary drainage of the aqueous humor through the part of the cornea which could not be reached by the iris tissue, and preventing the formation of any anterior synechia. The opening was kept free by repeated paracenteses until all conicity had disappeared. He states that the "opacity resulting from this mode of operating seems to be unexpectedly slight, but if required, it may be concealed by the tattooing process (Wells *Treatise on the Diseases of the Eye* [4th Am. Ed.], 1883, p. 252).

De Wecker and Warlomont also employed corneal trephines (*Rep. of the Fourth Internat. Ophth. Congress,* 1873, p. 183). The former's instrument was intended to make a fistula in a cicatrix, "which is usually very thick, and opposes considerable resistance." It was provided with a spring by which an instantaneous rotation was produced, "and during the rotation there is a retiring of the cutting edge from the cut surface."

Abadie (*Thèse de Guiot,* 1887) placed the cauterization area more towards the periphery of the cornea. He did not penetrate more deeply than Descemet's membrane. Sichel (Beard. *Ophth. Surgery,* 1910, 387) exercised the conic tip down to Descemet's membrane, followed by touching the operated-upon area with the mitigated stick

and the actual cautery. When healing had occurred, recurrent paracenteses in order to produce and to maintain a fistula in the hopes of further flattening the cornea were made.

Andrew (*Brit. Med. Jour.*, 1884, 2, p. 903) uses the actual cautery over the scarified area. Robert D. Gibson (Fox. *Practical Treatise on Ophthalmology,* 1910, pp. 232-233) penetrates the cornea with the galvano-cautery. He reports good results. Gayet (*Lyon médicale,* 30, 1879) has also made use of the penetrating effect of the cautery in such cases. Repeated cauterization with permanent marked improvement of vision has been successfully done by Schwenk (*Pennsylvania Medical Journal,* August, 1907). Ziegler (*Pennsylvania Medical Journal,* August, 1910) is of the opinion "that corneal perforation is requisite to success."

The galvano-cautery has been employed by Dodd (*Medical Press and Circular,* February, 1903, p. 171). He makes a series of cauterization points at about a millimeter's distance apart around the apex of the cone. The side towards the pupillary centre is not touched. He recommends repetition of the procedure if necessary. As Grimsdale and Brewerton (*Textbook of Ophthalmic Operations,* 1907, p. 333) say, "This method seems effective, and, inasmuch as the central zone of the cornea is untouched, the necessity for after iridectomy is reduced. The scar, however, does not support the weakest area (the centre or apex of the cone), and it would seem more liable to an extension of the disease." Del Toro destroys the vertex of the cone by a fine knife heated to a white heat, two weeks after having made an iridectomy, believing that the cauterization which leaves but a slight opacity, exercises a beneficial influence on any existing keratomalacia, and that the iridectomy tends to diminish any tendency towards increase of intraocular tension.

Swanzy (*Handbook of the Diseases of the Eye,* 1903, p. 176) tells us that "Multiple puncturings of the apex of the cone with a fine cataract needle have been employed." The summit of the cone is transfixed from three to six times at each sitting; this may be repeated at intervals of two weeks or more. The first effect of the punctures is to allow some of the aqueous humor to escape. The eye is firmly supported with a bandage, and the pupil is kept under the influence of eserine. "Eventually, a network of cicatricial tissue forms, which flattens the cone without giving rise to much corneal opacity." Higgens' plan has been modified as follows, by Morton: In the words of Swanzy (*Handbook of the Diseases of the Eye,* 1903, p. 176), "He excises an elliptical piece from the apex of the cone by transfixing it from above downwards, about midway between its base and apex with

a long narrow rigid Graefe knife, of which the edge is directed forwards and inclined slightly to the right. The knife is pushed onwards until it cuts its way out a little to the right of the apex of the cone, the aqueous escaping at the same time. The flap thus formed is then lifted up well by a fine forceps, and the knife—with its edge now turned to the left—is passed beneath the points of the forceps, and by cutting forwards, the flap is excised. The sides of the wound should be steep and incline towards each other at an angle of 30° to 45°. The apex of the cone being somewhat downwards and inwards, or outwards, from the centre of the cornea, it is important, in order to prevent an anterior synechia, to avoid carrying the incision too far downwards. The eye should be well soaked with atropine both before and after the operation." A firm compress must be kept on for some time after the wound is healed.

Morton (*Brit. Med. Jour.*, Sept. 26, 1903) repeatedly excises the apex of the cone. If there is any increase of intraocular tension, or if any disturbing optical conditions be present, he makes use of an iridectomy. He has also practised synechtomy and paracentesis of the cornea to advantage. His results with the cautery have been generally associated with perforation of the membrane. Swanzy (*Handbook of the Diseases of the Eye,* 1903) teaches that a satisfactory proceeding is the application of the electro- or thermo-cautery at a red heat to the apex of the cone. He says that the operation is practically free from risk. The cauterization must be confined to a small area at the apex of the cone and the cornea should not be perforated with the cautery. The operation, he states, may be repeated over the same area at intervals of ten to fourteen days, "to bring about a more intense cicatrix."

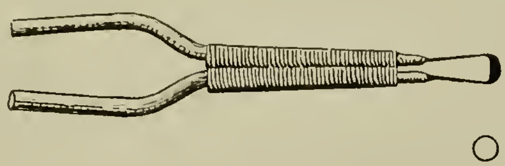
A Critchett (*Practitioner,* 1895, p. 426) lays much stress on the graduated application of the cautery. He first applies the cautery at a black heat to the whole area of the cornea intended to be cicatrized; within this area a little more is destroyed at a slightly increased heat; while the very apex is touched with a cautery at a dull red heat. One sitting, he tells us, is sufficient.

Tweedy (*System of Diseases of the Eye,* Norris and Oliver, Vol. 2, p. 252) pushes cauterization so far as to produce perforation "which he believes is essential to the production of a flattened cicatrix, and is without danger.

Herman Knapp (*Archives of Ophthalmology,* 1892, p. 40), speaking of the value of the galvano-cautery in keratoconus, states that his experience coincides with that of A. Critchett and Tweedy. Like Critchett, he grades his degree and areas of burning. He employs

convex disc electrodes applied directly to the parts (see figure). The largest area is superficially burnt the most; the middle zone is burnt to a less degree; while the central portion is burnt the least.

The burning, which when done properly and carried to perforation, is seldom, if ever, necessary to repeat. One-half of the pupillary area should, if possible, be spared. The best results, he finds, are obtained in the early stages of the progressive types of the disease. In regard to his experience with the use of cauterization, he gives the following interesting happening (*System of Diseases of the Eye,* Norris and Oliver, Vol. 3, p. 824): "At first I used a pointed burner, and pierced the cornea freely. The recovery was tedious, but the result perfect and permanent. Then I made the cauterization very cautiously and pierced the cornea so slightly that the aqueous did not jet, but oozed out. This took a longer time, and was followed in from



Galvano-Cautery Burner for Conical Cornea.

six to eight weeks by the formation of a peculiar-looking yellowish cataract (the patient was fourteen years old). The wound healed well, I extracted the cataract later, and the eye has had good sight ever since (eight years). I have always considered this cataract as due to the overheating of the aqueous humor during the cauterization, for I had never seen such a peculiar-looking cataract apart from its developing in a young and healthy eye."

Panas (*Traité des Maladies des Yeux,* 1894, p. 293) also indorses the experience of Critchett and Tweedy.

The apex of the cone is not burnt by Sgrosso (*Annali di Ottalmologia,* 18, 3, 1900). He makes as solid a cicatrix as possible—one which is able to resist intraocular pressure. To do this, the cautery point is applied to the temporal wall of the cone, and the burning is made as deep and as extensive as is safely possible.

Cauterization without perforation has been, in the hands of Wicherkiewicz (*Archives d'Ophtalmologie,* February, 1905, p. 87), the most satisfactory method of procedure.

Wolfe's (*On Diseases and Injuries of the Eye,* 1882, p. 85) plan is to tint over the cone and thus produce an opacity of the distended portion. He then makes a small artificial pupil in order to allow the rays of light to enter through the part of the cornea of more normal curvature. Grandclément (*Lyon médical,* March 2, 1891)

speaks of tattooing, not only as a cosmetic procedure for corneal opacities, but also as a curative measure in conical cornea: In the latter type of cases, Gayet attributes the happy results to the scarifications that are made.

Elschnig (*Wiener Klinische Rundschau,* May 15, 1904), believing that one of the requisites for success in the surgical treatment of keratoconus, is the prompt vascularization of the cauterized area, superficially burns the cone, which is generally eccentric, with a galvano-cautery at a dull redheat. He connects the cauterized area with the nearest point on the conjunctival limbus by a superficially burned band of the same width as the burnt corneal area. In several days' time, the bridge of superficial cauterization will become vascular, until in a couple of weeks' time, the cauterized area will be filled with many vessels. If the case is an almost centric one, the burned area should be placed to the side which is nearest to the corneal limbus. He does not think an optical iridectomy is necessary, and asserts that it may even prove harmful. In some cases he tattooes the after-opacity in order to prevent diffusion of light. He is daily on the watch for betterment of both local measures and systemic treatment.

Sattler (*Jour. of the Am. Med. Assoc.,* August, 1900) finds that the best surgical methods are the galvano-cautery as supplemental to iridectomy or iridotomy. In desperate cases he makes use of extraction of the lens, followed by superficial cauterization of the apex of the cone or corneal tattooing. He advises caution in the performance of any form of operative procedure, as it is usually tedious, and in the most favorable cases is associated with danger and uncertainty.

Beard (*Ophthalmic Surgery,* 1910, p. 389) states that if no progress is obtained by other than radical measures, "repeated paracentesis of the cornea is subjoined, to which might, as an ulterior measure, be added the application of a small galvanic tip, in three or four short meridional lines, near the base. "If these measures failed of material improvement, I (he writes) should still advise against more drastic surgical treatment save where the ectasia is very great and the vision very poor, so poor, indeed, as hardly to be called useful." He justly adds: "True, much depends upon the fellow eye. If this be possessed of fair sight, one may venture further."

As mentioned by Soelberg Wells (*Treatise on the Diseases of the Eye* [4th Am. Ed., Edited by Chas. S. Bull], 1883, p. 253): "At present it must be admitted that all these modern methods of treatment of conical cornea are still upon their trial, and nothing decisive can as yet be said as to their relative advantages and disadvantages."

As then, so now! Though this is so, the writer cannot share the pessimistic views of Lawrence, who, in the light of his day, said: "If we do not know the cause of the affection, we cannot be prepared to propose any rational treatment. I cannot say that I have seen any plan productive of benefit."

The writer is deeply impressed with the importance of careful and repeated correction of the refractive errors and the employment of suitable dises in such cases in spite of the diminished field of vision and decreased illumination; limiting his operative work to those few instances which cannot be apparently bettered in any other way, and choosing that form of procedure, which seems to be the best adapted in each individual case.—(C. A. O.)

Conical cornea, Shells for. These artificial devices, made of transparent glass, are called by the French *contact glasses.* They are adjusted intimately to the eyeball and were recommended in irregular astigmatism and keratoconus to give a regular contour to the front of the cornea and so improve the visual powers and cosmetic appearance of the eye. In some cases there was a space between the outer layer of glass and the cornea (or the shell was hollow) to be filled with a 50 per cent. glucose solution which is of the same refractive index as the cornea. Sulzer found them non-irritating and of great benefit in improving vision. About 1871 Albini invented a plate or cover of aluminum for the front of the eye, to be held in place by the lids. He called this device an opistoblepharos and claimed that it was useful (a) in staphyloma corneæ upon which it might exercise beneficial mechanical pressure; (b) to protect the bulbar conjunctiva from cauterants applied to the lids; (c) as protection to the cornea in ulceration of the latter; (d) when covered with a certain composition it would take the place of the artificial eye; (e) it might act as a frame to carry minute quartz lenses and thereby be a substitute for ordinary glasses; (f) it might be useful as an electrode in applying electricity directly to the globe. Few of these claims have been justified in practice.

Conical hydrophthalmia. See **Conical cornea.**

Conical probe. An instrument (recommended by Theobold and others) with a cone-shaped end employed for dilatation of the lachrymal punctum and canal.

Conical refraction. The refraction of a single ray into an infinite number of rays in the form of a hollow luminous cone.

Conic cornea. See **Conical cornea.**

Conicina. (It.) Coniine.

Conicine. See **Coniine.**

Conicité pellucide de la cornée. (F.) Transparent corneal staphyloma.

Coniine. Conicine. Cicutine. An alkaloid, $C_8H_{17}N = C_8H_{16}(NH)$, homologous with piperidine, obtained from poison hemlock—*Conium maculatum.* It is a colorless, oily liquid of a penetrating, mouse-like odor and acrid taste, readily soluble in alcohol, ether, oils, but almost insoluble in water. It has a decidedly alkaline reaction, and its salts are crystallizable. It is a powerful poison, and is but little used. The soluble hydrobromide and hydrochloride are the most important salts of this fluid alkaloid.

Its use in the eye is limited; in scrofulous ophthalmia (q. v.) it is occasionally employed as a collyrium. It relieves the pain and palpebral spasm incident to the disease. When employed in this way it is used as a lotion, from 1 to 4 minims (0.05 to 0.25 c.c.) being dissolved in a fluid ounce (30.00) of water, or water containing ten per cent. alcohol.

Coniinvergiftung. (G.) Poisoning with conium.

Conina. (It.) Coniine.

Conine. Coniine.

Coni retinæ. (L.) Retinal cones.

Conium. See **Coniine.**

Conium maculatum. (L.) Spotted or poison hemlock. Poison parsley. Spotted cowbane. The full-grown but unripe and thoroughly dried fruit of this plant is used in medicine. It contains coniine, conhydrine, pseudoconhydrine, methylconiine, some volatile and fixed oils, as well as coniic acid. It acts as a narcotic, anodyne, and antispasmodic, and is mostly used in the form of *coniine.* The fruit and its derivations are powerful poisons, and are occasionally used in ophthalmic practice. There are a few records of its oculotoxic effects, one of which is described by Weller (*Brit. Med. Jour.,* 1893, Vol. 2, p. 116). A woman took a large dose of extract of conium, after which she had, amongst other signs of poisoning, widely dilated and unequal pupils and ptosis in both eyes. The same symptoms, including temporary but complete blindness, have been observed in other patients.

Conjonctive. (F.) Conjunctiva.

Conjonctive des paupières. (F.) Palpebral conjunctiva. Tarsal conjunctiva.

Conjonctive du globe oculaire. (F.) Bulbar conjunctiva.

Conjonctive granulée. Conjonctive granuleuse. (F.) Granular conjunctiva.

Conjonctivite. (F.) Conjunctivitis.

Conjunctivite aphtheuse. (F.) Aphthous conjunctivitis.
Conjonctivite blennorrhagique. (F.) Gonorrheal or blennorrhagic conjunctivitis.
Conjonctivite diphthérique. (F.) Diphtheritic conjunctivitis.
Conjonctivite morbilleuse. (F.) The conjunctivitis of measles.
Conjonctivite varioleuse. (F.) The conjunctivitis of small-pox.
Conjugate centers, Disease of the. In this condition one deals with "paralysis of motion, rather than of muscle." Duction power, which is reflex in the sense that it is not volitional, is not involved. This statement covers all the conjugate brain-centres from the first to the fifth, inclusive—those centres that are concerned with the recti muscles. Since there is no voluntary action of the oblique, the cortical centres (if there be such) governing them must act independently of the will. These centres are the sixth, seventh, eighth and ninth. That these conjugate centres for the obliques may be involved in pathologic changes must be conceded. Since the object of the sixth and seventh centres is to prevent diplopia, on looking down and up, respectively, these correspond perfectly in action with the reflex centres of the recti that are also concerned with the prevention of diplopia when images are displaced by prisms; therefore they ought not to be affected in disease of the cortex. The eighth and ninth centres are not concerned with the prevention of diplopia; but, what is probably of as much importance, they are concerned with the steadying of all objects in the field of vision whenever the eyes are voluntarily moved in an oblique direction. For instance, when the gaze is directed up and to the right, or down and to the left, the eyes would be torted to the right, were it not for the eighth conjugate center, when all objects would be made to appear to incline to the left from their real position, their inclination corresponding precisely with the degree of torsioning. This is prevented by the eighth conjugate centre, which maintains the parallelism between the vertical axes and the median plane of the head in such a voluntary rotation. It appears, therefore, that disease of this centre would be attended by a wheel-like movement of objects whenever the visual axes are made to move up and to the right, or down and to the left, which appearance would not be if the gaze were directed up and to the left, or down and to the right. But if the ninth conjugate centre were involved in pathologic change, the wheel-like movement of objects would be observed only when the gaze is up and to the left, or down and to the right. In neither case would there be diplopia. Should the sixth conjugate centre be involved, on looking down at a candle it would appear double, the one seen by the right eye leaning to the left and the one seen by the

left eye leaning to the right; the diplopia would be attended by dizziness and nausea. In the upper field there would be no diplopia. Should the seventh conjugate centre become diseased, the diplopia would be in the upper field, and the candle seen by the right eye would lean to the right, and the one seen by the left eye would incline to the left. It appears that each oblique muscle is connected by individual nerve fibres with three centres—one centre, basal; the two others, probably cortical. The former centre has connected with it fibres from only one muscle, but each of the latter has connected with it fibres from two oblique muscles, one of these belonging to one eye and the other to the other eye; and, therefore, they are conjugate centres. All the fibres from these three centres come together and form the trunk of the nerve, a disease of which suspends the independent and conjugate action of the muscle supplied by it; and the muscles of the fellow eye are not involved. The right superior oblique is connected with the sixth conjugate centre, as is also the left superior oblique; the right superior oblique is also connected with the eighth conjugate centre, as is also the left inferior oblique. Disease of the sixth centre, as already shown, gives trouble only when looking directly down; disease of the eighth centre causes trouble, as shown above, only when looking up and to the right, or down and to the left. Disease of these two conjugate centres would have no influence over the basal centre that gives duction or fusion power to either of the two muscles mentioned—that power that is exercised when images are displaced by oblique astigmatism, natural or artificial. Each rectus muscle is also connected with three centres—one centre, basal; the two others, cortical. The former is reflex; the latter, volitional. To illustrate: The right internus has its reflex centre—the centre giving it duction or fusion power—in the nucleus of the motor oculi; it is also connected with the third conjugate brain-centre, as is also the left internus; it is also connected with the fifth conjugate centre, as is also the left externus. All the fibres from these three centres for the right internus form the bundle that constitutes the branch of the third nerve, supplying it with its threefold power. Disease of this branch suspends both the reflex (fusion) and voluntary power of this muscle; it can neither adduct, converge, nor advert the eye to which it belongs. Disease of the third conjugate centre involves only those fibres that convey to the muscle the convergence impulse; disease of the fifth conjugate centre involves only those fibres that convey the adversion impulse; likewise disease of the reflex nucleolus involves only those fibres that convey the fusion impulse. Disease of the third conjugate centre would suspend, of course, the converging power of

the left internus also; while disease of the fifth conjugate centre would affect the abverting power of the left externus as well as the abverting power of the right internus. Thus each muscle, with its several centres, might be studied. It only remains to speak of the symptoms that would present themselves, should any one of the five conjugate centres, controlling the recti, become diseased: (1) Disease of the first conjugate centre: inability to supervert the eyes, but no diplopia; (2) disease of the second conjugate centre: inability to subvert the eyes, but no diplopia; (3) disease of the third conjugate centre: inability to converge the eyes, with diplopia in the near; (4) disease of the fourth conjugate centre: inability to rotate the eyes to the right, either cardinally or obliquely, but no diplopia; (5) disease of the fifth conjugate centre: inability to rotate the eyes to the left, either cardinally or obliquely, but no diplopia.

Treatment.—In any form of paralysis of muscle—that is, when the disease causing it is below the internal capsule—the diplopia should be prevented by covering the affected eye, which will relieve all nervous symptoms, such as headache, dizziness, and nausea. The affected eye should be kept under cover until the disease has been cured. In paralysis of the third nerve, nature supplies the cover in the production of ptosis, and usually the last muscle, supplied by the third nerve, to regain its power is the elevator of the upper lid. If any case is clearly rheumatic, it should be treated with large doses of the salicylate of sodium or other anti-rheumatic remedy; if the cause is syphilis, iodide of potassium in increasingly large doses should be given after meals; if the cause is not known, the case should be treated with the iodide of potassium. Early in any case the administration of the fluid extract of jaborandi, in doses of twenty drops at 9 A. M., 3 P. M., and 9 P. M., by promoting absorption of effused serum, will greatly aid the iodides in the work of hastening the absorption of plastic effusion. Bichloride of mercury in small doses may also be given.

If a Wassermann or other reliable test shows the presence of lues salvarsan, neosalvarsan or a similar preparation should also be given. The above remedies should be continued until the diplopia has entirely disappeared. This much having been accomplished, the sulphate of strychnia in doses of 1/100 to 1/50 of a grain should be given before each meal. At this stage the interrupted current of electricity, used once daily for ten minutes, will do good. While there is still diplopia, the strychnia and electricity would do harm, rather than good. In old cases of ocular paralysis, when there can be no longer any hope of restoration of power to the paralyzed muscle, surgery will do good,

in that it will lessen the field of diplopia and give to the patient a more natural pose of the head. The operation should be either an extensive shortening or advancement of the paralyzed muscle, and never even a partial tenotomy of the antagonist. The muscle plane should be changed or not, when making the shortening or advancement, as may be indicated by the existence or non-existence of torsion.—(G. C. S.)

Conjugate foci. Two points of such a position that light-rays, heat-rays, or sonorous vibrations emanating from one are collected by a mirror or lens at the other. Conjugate foci are mutually convertible, i. e., either one may be taken as the point of emanation of the rays or vibrations, and also as the point of collection of the latter.

When a luminous point beyond the principal focus sends rays to a convex lens the emergent rays converge to another point; the two points thus related are called *conjugate foci.* When rays diverge from a point whose distance is equal to, or greater than, the principal focus, the conjugate focus is *positive;* when the distance is less than the principal focus, the conjugate focus is *negative.*—(J. M. B.) See, also, **Focus.**

Conjugate innervations. To accomplish their work the ocular muscles have nine conjugate innervations: (1) The one to elevate both eyes; (2) the one to depress both eyes; (3) the one to converge both eyes; (4) the one to move both eyes to the right; (5) the one to move both eyes to the left; (6) the one to keep the vertical axes from diverging above; (7) the one to prevent their converging above. These (6 and 7) are called into action by the guiding sensation, when the point is primary or in either one of the four cardinal directions; (8) the one to maintain the parallelism of the vertical axes and the median plane of the head when the point of view is obliquely up and to the right, or down to the left; and (9) the one to maintain the parallelism of the vertical axes of the eyes and the median plane of the head, when the point of view is obliquely up and to the left, or down and to the right. The innervations one to five are for the recti, and the sixth, seventh, eighth, and ninth are for the obliques. Each of the conjugate innervation centers controls two muscles, one for either eye. The first controls the two superior recti; the second, the two inferior recti; the third, the two interni; the fourth, the right externus and the left internus; the fifth, the left externus and the right internus; the sixth, the two superior obliques; the seventh, the two inferior obliques; the eighth, the right superior and the left inferior obliques; and the ninth, the left superior and the right inferior obliques. The cerebral centers for these innervations have not been located. These centers are so intimately related

that their innervation impulses cause the normal muscles to act in perfect harmony. The first and second conjugate innervations, acting in harmony, *plane* the visual axes; the third, fourth, and fifth regulate the angle of convergence of these axes; while the sixth, seventh, eighth, and ninth maintain parallelism between the vertical axes and the meridian plane of the head.—(G. C. S.)

Conjugate lateral deviation. This is a symptom that occurs in a number of diseases of the nervous system, especially in epilepsy. The eyes turn to the opposite side of the body from that in which the convulsive movements began, the head inclining in the same direction. Later the eyes are directed in the opposite direction. See **Conjugate centers, Diseases of the.**

Conjugate lateral paralysis. Failure of the eyes to move conjointly to the right or left, is due to a lesion in the centre for associated movements, the situation of which has not been positively determined. An irritation of the cortical region of the fifth nerve will produce conjugate movements to the opposite side, and it has been shown that destructive lesions of the cortex will produce a *paralysis of associated movements* to the opposite side. The antagonists draw the eyes away from the paralyzed side of the body, but toward the side of the brain lesion. If the lesion is in the pons, the opposite side of the body is paralyzed, but by the involvement of the nucleus of the sixth nerve—which is in close proximity on the same side of the pons—the external rectus muscle of the same side is paralyzed, and the eye turns in the opposite direction—toward the paralyzed side of the body. Irritative lesions in the same situations would have the opposite effect.—(J. M. B.)

Conjugate mirrors. Two mirrors placed face to face so that rays of light and heat sent out from the focus of one are reflected to the focus of the other.

Conjugate points. A point and the image of that point are together designated as *conjugate points.*

Conjugatio prima. (L.) Optic nerve.

Conjugirte Ablenkung der Augen. (G.) Conjugate deviation of the eyes.

Conjugirte Augenbewegungen. (G.) Conjoined movements of the eyes.

Conjugirte Augenmuskellähmungen. (G.) Conjugate paralysis or paresis of the eye muscles.

Conjugirte Brennpunkte. Vereinigungspunkte. (G.) Conjugate foci.

Conjugué. (Adj.) (F.) Conjugate.

Conjunctiva. The mucous membrane covering the anterior portion

of the globe of the eye, reflected on, and extending to the free edges of the lids. Its parts are called *palpebral,* and *ocular* or *bulbar.* (Gould.) See **Conjunctiva, Ocular.**

Conjunctiva, Abscess of the. Occasionally a circumscribed collection of pus takes place in the conjunctival tissue independent of trauma or other morbid process. It is more apt to be found in the caruncle, which being somewhat dermoid in structure, is more likely to be the seat of an idiopathic abscess. One such case was observed by Burnett in the conjunctiva of the ball to the outer side between the external and superior recti. There was no history of injury, nor were the surrounding tissues of the orbit or eyeball affected. Hot applications and an early opening are the indicated therapeutics. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Acid burns of the. See **Conjunctiva, Injuries of the**; as well as **Injuries of the eye.**

Conjunctiva, Acne rosacea of the. This condition is sometimes seen accompanying acne indurata of the face. The ocular conjunctiva is usually affected. The condition closely resembles phlyctenular conjunctivitis.

Conjunctiva, Adenoma of the. A tumor in the conjunctiva, that has sprung from a gland, or is constructed after the type of a secreting gland. See **Conjunctiva, Lymphoma of the.**

Conjunctiva adnata. (L.) Bulbar conjunctiva. The mucous membrane covering the anterior third of the eye-ball, from the fold of transition, or retrotarsal fold, to the corneal margin. It is loosely connected with the sclerotic, is much thinner than the conjunctiva covering the retrotarsal fold, and loses its papillary structure. The epithelium of the ocular conjunctiva is continuous with the anterior corneal epithelium.

Conjunctiva, Amyloid degeneration of the. Hyaline degeneration of the conjunctiva. This rare form of degeneration of the conjunctiva has been observed principally in Russia. Its chief peculiarity is the presence of amyloid bodies in the much thickened conjunctival tissue. The hypertrophy is very great, the conjunctiva sometimes protruding from between the lids in large folds. The homogeneous material formed by these degenerative changes varies very much in its staining reactions, and on this account has received various names, such as hyaline, colloid, amyloid, etc., and this has led to great confusion. In all probability these substances are entirely formed from exudates or secretions, *i.e.* from the non-living products of living cells (Parsons). It has a waxy appearance, is smooth and of some consistency, and does not bleed easily when roughly handled.

It begins usually in the retrotarsal folds, but successively invades the bulbar and tarsal portions and caruncle. The upper lid particularly is much thickened, and too heavy to be lifted, and as a consequence there is complete ptosis. The hypertrophied tissue sometimes falls down in folds over the cornea, which latter, however, is not affected. The disease is very chronic in its course, continuing years. There is no discharge or lachrymation, and no pain. It has been thought by some to be a sequel or a very exaggerated or modified form of trachoma, which seems possible, since both appear to be diseases of the adenoid tissue of the conjunctiva; but there is no doubt that it can be an entirely independent affection, and strictly local in its manifestation without the concomitant appearance of the same kind of degeneration

Colloid Degeneration of the Conjunctiva.
Showing epithelium above with swollen cells, the deeper tissues infiltrated with leucocytes and containing hyaline masses.

in any other part of the body. It is Raehlmann's opinion that the amyloid bodies are seen only in the later stages of the peculiar degeneration, and that their presence is not necessary for a diagnosis of the disease. The first step is a simple hypertrophy of the conjunctiva, an increase in its adenoid elements, such, for instance as that described as lymphoma. The next step is a hyaline degeneration, and the final one is the appearance of the amyloid bodies. (See figures.)

The only treatment is operative, and Raehlmann has found that a partial extirpation is almost always followed by atrophy and final disappearance of the remainder of the hypertrophied mass. (Burnett.)

Kolominsky (*Klin. Monatsbl. f. Augenheilk.*, Nov., 1912) describes a case of hyaline amyloid degeneration of the lid conjunctiva which

differs from previously reported cases in showing many newly-formed blood vessels. He therefore thinks that we have to deal with an angioma-like growth in which a hyaline amyloid degeneration developed which did not limit itself to the connective tissue, but involved the vessels and their contents. A mass of amyloid substance formed in this way and became surrounded by a kind of connective tissue capsule which was formerly vessel wall. Leber attributed to this capsule the production of the amyloid substance, but Kolominsky found no cell elements which showed changes that might be considered evidence of amyloid degeneration.

Wützold (*Ophthal. Review,* June, 1913) records the case of a woman of 50 years who had acquired trachoma six years previously; she had been treated for two years. She had presented herself now on account of watering of the left eye. In both eyes he found greyish-yellow, glassy, tumor-like growths in the conjunctiva, smooth on the surface; there was also considerable scar formation. The condition somewhat resembled granuloma and sarcoma, but the little masses were more brawny and protruding and the diagnosis of amyloid was successfully arrived at, and confirmed with the microscope.

V. Ruata (*Archivio di Ottalmologia,* XIX, p. 526, 1913) has also described a case in a woman of 62 years, who had otherwise been free from both general and ocular disease. It had begun ten years earlier with a fleshy formation near the left caruncle, which for five years continued to extend. Three years later the disease started from a similar point in the other eye. At the time of examination there was a compact thickening of both lids of the left eye, and beneath the bulbar conjunctiva of this eye were a number of yellowish masses, of a fatty consistency. In the right eye there was a large yellowish mass at the inner angle of the bulbar conjunctiva. Microscopic study showed the subepithelial adenoid tissue to be almost completely replaced by a substance giving the characteristic reactions for amyloid. The blood vessels were compressed or obliterated by the abnormal tissue, but never themselves showed amyloid degeneration. The general process is to be regarded as an infiltration rather than a degeneration.

Conjunctiva, Anesthesia of the. A somewhat uncertain symptom, found in neurotic and hysterical subjects. A similar lack of reaction to excitation may be observed in indolent but otherwise healthy individuals.

A case was reported by Lawford (*Trans. Ophth. Soc. of United King.,* 1907) of a six-year-old child under treatment for an ulcer of the left cornea, who was discovered to have anesthesia of the con-

junctiva and cornea of both sides. Sensation was lost over the whole of the ocular and palpebral conjunctiva, and there was no reflex movement when the corneæ were touched. The child in no way resented the application of drops to the eyes. There was no loss of sensation in the skin, or in other mucous membranes supplied by the trigeminal nerve.

In cases of hysterical amblyopia it is not uncommon to see not only the skin about the lid, but also the conjunctiva and cornea absolutely insensitive. This occurs so frequently, especially in the left eye, that it is regarded by Briquet as characteristic of this condition. According to Féré, when the anesthesia of the cornea and conjunctiva is complete, the oculo-palpebral reflex is defective. If the cornea and conjunctiva is touched by a roll of paper, the eye being carefully fixed on an object, the lids remain motionless as long as the pupillary area is not touched. The reflex is excited by the effect upon the retina rather than from the irritation of the conjunctiva or cornea. The lid movements, however, are normally executed in this condition, and the lachrymal reflex is not interfered with. A piece of paper brought into contact with the insensitive conjunctiva will cause an immediate secretion of tears as abundant as when the mucosa preserved its normal sensibility, as pointed out by Gilles de la Tourette. The glandular reflex is also preserved in this condition, according to Pitres.

Among the ocular signs of death, which are not many, insensibility of the conjunctiva and the cornea, like general anesthesia, is more striking than elsewhere seen. This is so on account of the exquisite sensibility of these tissues during life. Tourdes states that sensibility does not disappear simultaneously in both conjunctiva and cornea. The latter membrane which is supplied by filaments from the ophthalmic ganglion, retains its sensibility longer than the former which is supplied by filaments from the fifth pair. Furthermore, sensibility passes away differently according to the kind of death. Section of the globe, etherization, poisoning by curare, and strangulation paralyze the conjunctiva before they do the cornea; while cold and strychnine kill the cornea first, and leave the conjunctiva, especially towards the inner angle, longer sensitive. Absolute insensibility of the two membranes does not prove death, it being often seen while life undoubtedly exists, as for example, during anesthesia and syncope.

The color and appearance of the vessels on and under the conjunctiva should have great value in this connection, since they are readily observed objective signs. Exsanguinated blood-vessels can easily be distinguished from full ones, and the color of living tissues is readily differentiated from cadaveric lividity. In an emaciated sub-

ject, dead of disease for a moderate length of time, in winter, the pallor of the conjunctiva is characteristic; while on the other hand, in a person dying suddenly in warm weather, a lividity of the same tissues, accompanied by slight edema, is often present. (Gayet.)—(C. P. S.)

Conjunctiva, Angioma of the. A tumor of the conjunctiva formed of blood-vessels.

Two cases of this rare affection are reported by Castelain (*Annales d' Oculistique,* Feb., 1907), who says the seat of election is the internal angle of the eye in the region of the semilunar fold. The structure of angioma of the conjunctiva is that of angioma in general. In the majority of cases, if not in all, the disease is congenital.

The symptoms are chiefly of mechanical origin. Hemorrhage is usually not severe, but Fuchs has reported a case in which the patient nearly bled to death from a very small conjunctival angioma. The evolution is variable. The disease sometimes remains stationary and sometimes increases slowly or rapidly. The tumor may disappear spontaneously during the first months after birth, but later there is no hope of such a termination. As to prognosis, angioma of the conjunctiva may generally be considered as a benign tumor of slow growth, though the prognosis may sometimes be more serious on account of the danger of abundant hemorrhage or the possibility of transformation into a malignant growth. The author advises excision, thermocauterization or electrolysis. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Angio-neurotic edema of the. A swelling, with associated symptoms, probably due to vaso-motor lesion (Gould). Terson and Jocqs in 1899 reported cases of intense chemosis, of sudden development, unattended by pain, increased secretion, or other evidences of inflammation, and which disappeared completely in two days. In one case, it was unilateral, in the other bilateral. This edema is in all probability simply an example of angio-neurotic edema seen occasionally upon the lids, cheeks, or other portions of either skin or mucous surfaces.

To be included in the same category, are some cases in which the condition is one of hyperemia rather than edema, and therefore much more transient.

Conjunctiva, Argyriasis of the. ARGYROSIS OF THE CONJUNCTIVA. COLORATION OF THE CONJUNCTIVA. SILVER STAINING OF THE CONJUNCTIVA. This subject has been partially discussed on page 574, Vol. I, of this *Encyclopedia,* since which a number of cases of discoloration by silver salts, but especially by argyrol, have occurred.

Nitrate of silver produces the most pronounced staining of the con-

junctiva (argyrosis). This is always liable to happen when the silver salt is used for a long time as a local application, and especially if it is not immediately neutralized by chloride of sodium. A yellow coloration of the conjunctiva may result from the prolonged use of sulphate of iron (siderosis conjunctivæ). The brown spots which are sometimes seen on the conjunctiva, especially among negroes, are due to deposits of pigment and are usually congenital; yet this brown coloration is much intensified in some diseases, notably the circumcorneal hypertrophy of the conjunctiva. After dislocation of the iris under the conjunctiva a permanent black patch sometimes remains.

Komoto (*Centralbl. f. pkt. Augenheilk.*, May, 1913, p. 134) of Tokio reports the case of a young man eighteen years of age, who had been treated for a year with instillations of nitrate of silver and showed intensely black ocular and palpebral conjunctivæ. Since chemicals (sulphate of sodium) had no effect, Komoto removed a kidney-shaped piece of the ocular conjunctiva, extending from the cornea to both ocular angles and the lower half, and transplanted a piece of ocular conjunctiva from the enucleated eye of another patient, fixing it with a suture at the lower limbus, the lower margin of the wound and at each lateral angle. The cosmetic effect after about three weeks was excellent.

The method of decolorizing the conjunctiva when stained by silver, as recommended and employed by Schwarz (*Ophth. Record,* XX, p. 24), consists of injection into the conjunctiva of potassium iodide in saturated, half saturated, or thirty per cent. solutions, the strength depending on the reaction following each treatment. With the smallest needle of an ordinary hypodermic syringe and a broad-sided forceps, a puncture of some portion of the stained area is made, and the needle is passed superficially eight millimetres or more into the substance of the conjunctiva, care being taken to keep parallel to and as near the surface as possible. Three or four minims of the solution are injected very slowly. If the discolored area is extensive and the reaction is slight, the injection may be repeated at a point as far removed as possible from the first. When all irritation has subsided, which usually requires from two to three weeks, the injection may be repeated at other points, until the stained area has been well traversed. The effect of potassium iodide so far as decolorization is concerned is progressive and slow, but certain, producing an almost normal color in the conjunctiva. See, also, **Conjunctiva, Staining of the.**—(C. P. S.)

Conjunctiva, Argyrosis of the. Same as **Conjunctiva, Argyriasis of the.**

Conjunctiva arida. (L.) Xerosis of the conjunctiva. See **Conjunctiva, Xerosis of the.**

Conjunctiva, Arteries of the. There are no arteries of any size in the conjunctiva, but there is a very rich network of minute vessels which come into view in inflammation. It is noted for its irregular arrangement, and may be distinguished by this and its mobility from a deeper system of vessels connected with the interior of the eye-ball. See **Anatomy of the human eye.**

Conjunctiva, Atrophy of the. See **Conjunctiva, Xerosis of the.**

Conjunctiva, Bacteriology of the. The normal conjunctiva of the newborn, according to Koblank, who investigated twenty cases by culture experiments, is free from bacteria. Xerosis bacilli and staphyloeocci were found in some cases on the second day; in others the conjunctiva was still sterile on the sixth day. In any case the bacteria are few during the first ten days.

Because of its intimate proximity to the skin, and being exposed to the air, it is not surprising that the conjunctival sac should contain many bacteria from these sources.

Sterile conjunctivæ have been found, however, in a surprisingly large proportion of eyes examined by various observers, though the number of organisms varies greatly and their nature, pathogenicity, and the possibility of sterilization are subjects of much dispute.

The *xerosis bacillus,* and next to this the *staphylococcus albus* are most commonly found (Heinersdorff, Lawson, Axenfeld, Gifford).

Oertzen found the pneumococcus in four per cent. of cases. Lawson found it twice in two hundred cases. According to Parsons, small diplococci are not uncommon in the conjunctiva, and they probably include many species, some of which have been mistaken for pneumococci. The staphylococci found are usually of slight virulence. Virulent pyogenic staphylococci (*aureus* and *albus*), streptococci, etc., are rare. Other pathogenic and non-pathogenic bacteria are found occasionally. Lobanow found that among the non-pathogenic organisms the *sarcina lutea, proteus,* B. *subtilis, prodigiosus, agilis, fluorescens, putridus,* and *micrococcus roseus,* introduced into the anterior chamber and vitreous of the rabbit, produced a slight, non-progressive inflammation. Organisms can be transported from the conjunctiva to the nose within twenty-four hours according to Bach, but transference from the nose to the conjunctiva could never be obtained with the normal flow of tears. The bactericidal property of tears is as yet by no means definitely proved. (Axenfeld.) The tears are doubtless a bad culture medium.

The possibility of sterilizing the conjunctiva is a question of grave practical importance. It was demonstrated by Bach that mechanical purification of the lids, combined with irrigation of the conjunctiva

with saline solution, led to great diminution in the micro-organisms, amounting to sterilization in nearly half the cases. Many authors emphasize the importance of non-irritating lotions. It is generally admitted that complete sterilization is in most cases unattainable. Hauenschild published statistics of the Würzburg clinic from 1893 to 1898—1,944 operations upon the globe, including 549 cataracts—with asepsis only, and only one suppuration. Bandaging a wound until it is closed, after which allowing the free movements of the lids, seems to produce the most favorable results in diminishing the development of bacteria. See **Bacteriology of the eye.**—(C. P. S.)

Conjunctiva, Benign growths of the. These neoplasms will be described under their separate headings. Among them are the so-called *granulation tumor* that accompanies the healing of various wounds and injuries of the conjunctiva. It is not uncommon after strabismus operation and constitutes the button of "proud flesh" that springs, in part at least, from the operation wound after enucleation. Other non-malignant growths are *polypus, papilloma* (soft fibroma), *dermoid tumors, lipoma, cysts* of various kinds, *osteoma, angioma* —including hematoma and true varix—while *lymphectasia* of the conjunctiva is not uncommon. See **Conjunctiva, Tumors of the,** also **Tumors of the eye.**

Conjunctiva, Bone in the. Vavoolin (*Viestn. Oft.,* Nov., 1912) of St. Petersburg reports the case of a country woman 24 years of age, in whom numerous white grains were seen on the thickened fornices of both lower lids, on the caruncles, semilunar folds and the conjunctiva of the left upper lid. Microscopical examination showed them to possess the structure of true bone with complete Haversian systems and bone corpuscles. Only the deeper part of the nodules consisted of bone, the more superficial portion showed the appearance of amyloid degeneration. There was no evidence of antecedent trachoma.

Conjunctiva bulbi. (L.) Bulbar conjunctiva. That portion of the mucous membrane which is reflected upon the eye-ball covering its anterior third. See **Conjunctiva, Ocular.**

Conjunctiva, Burns of the. See **Injuries of the eye.**

Conjunctiva, Calcareous. Conjunctivitis petrificans. Small, whitish bodies are frequently seen buried in the conjunctiva of the inside of the lids, generally near the edge. They are hard, almost round, and usually extend above the level of the conjunctival surface. They are calcareous formations, and are lodged in the Meibomian glands, of whose secretion they seem to be the degeneration. Old people are most frequently the subjects of these little tumors. Often they give rise to no special inconvenience, but sometimes they are a source of irrita-

tion and keep up a subacute conjunctivitis. They are easily removed with the point of a Graefe knife.

Leber in 1895 described a case of what he called *conjunctivitis petrificans,* where the conjunctiva is the seat of an inflammatory swelling in which white opaque spots were to be seen that increase in size and finally coalesce, forming a mass as hard as stone. An examination of these concretions shows them to be a calcareous infiltration of the conjunctival tissue.—(C. P. S.) See **Conjunctivitis petrificans.**

Conjunctiva, Carcinoma of the. See Vol. II, page 1409, of this *Encyclopedia,* as well as **Conjunctiva, Malignant tumors of the.**

Conjunctiva, Caterpillar hairs in the. See **Conjunctivitis nodosa.**

Conjunctiva, Chancre of the. Although this subject has already been discussed in Vol. III, p. 1997 of this *Encyclopedia* a few additional observations may not be out of order.

The possibility of the occurrence of a primary sore in the most out of the way places, is well illustrated in a case presented by Ellett in 1899, before the Memphis Medical Society, in which the diagnosis of this condition seemed sufficiently plain. The patient was given a solution of boric acid, but no internal treatment, as it seemed best to await the appearance of the secondaries to convince the patient of the nature of his trouble. He was not inclined to believe that it was specific. Four weeks from the beginning of the eye trouble a syphilitic roseola appeared on the body. This eruption was quite typical and there was at this time general adenopathy.

When first seen the condition had persisted for four days and presented externally the appearance of a moderate-sized chalazion, situated at the inner extremity of the upper lid. On everting the lid an ulcer rolled into view. The edges were elevated and whiter than the centre, and the base was firm and unyielding. There was a moderate amount of secretion, no pain, but a stiff sore feeling, with the surrounding ocular and palpebral conjunctiva injected. The preauricular gland on the right side was much enlarged and quite hard. and the superficial cervical glands in front of and behind the sterno-mastoid as well. There was no history of possible infection, except that he had often washed his face and hands in hotel lavatories and dried them on the public towel.

Pons y Marques Mahon (*Archivos de Oftalmologia,* Jan., 1913), reported the case of a woman of nineteen years who came complaining of pain in the right eye. There were violent inflammation and chemosis of the conjunctiva, vision was not disturbed, and there was no increase of pain on pressure. There was some enlargement

of the submaxillary glands, but the patient was thought to be tuberculous. Five days later the swelling of the conjunctiva and lids was much worse, and the submaxillary glands had considerably increased in size and were tender to pressure. On everting the upper lid a rather hard ulcer was found on the upper part of the bulbar conjunctiva. Doubt was now felt as between syphilitic and tuberculous infection. Inoculation of a rabbit's eye with the exudate from the ulcer proved negative. The cornea became involved, having the appearance of an interstitial keratitis, and the cervical glands became enlarged. Intensive antisyphilitic treatment by injections of cyanide of mercury produced a rapid retrogression of all the ocular symptoms, although it did not prevent a typical secondary syphilitic eruption. It was discovered that the patient's fiancé had complained for some time of throat trouble for which he had received no medical attention, but which now proved on examination to be syphilitic. See, also, **Chancre of the conjunctiva.**

Conjunctiva, Chemosis of the. Edema of the conjunctiva. Because of the loose texture of its tissue, the conjunctiva easily becomes the seat of effusions of various kinds. One of the most common of these is that of blood-serum, causing the condition known as edema, or chemosis, in which the cornea is seen as if in the bottom of a crater-like elevation of the surrounding conjunctiva. It may accompany inflammatory conditions of the conjunctiva itself, or of the iris, or the ciliary body, and is sometimes a prominent symptom in these conditions. It is found in acute glaucoma, in affections of the orbit, and sometimes in those of the lids. It is always indicative of an obstruction to the return flow of the circulation. The degree of inflammation is not always indicated by the amount of chemosis, for it frequently happens that there is a large amount of effusion with but slight pathological change. The condition of the vascular walls undoubtedly has much to do with the origin and amount of the effusion. Sometimes there is a chemosis without any inflammatory symptoms whatever. This usually occurs in old persons, and is probably due to some temporary local interference with the circulation, the so-called *idiopathic chemosis.*

We occasionally find a chemosis coming on suddenly in apparently strong and healthy persons, due to some disturbance at the nerve-centres, the result of a toxic agent. Burnett observed a marked chemosis of the conjunctiva and lid following the ingestion of a single grain of quinine. Burning and itching of the conjunctiva, with hyperemia, have been noticed, with the same condition of the face, in attacks which were probably *urticaria,* and caused by the ingestion of food which had before produced general urticaria.

A pure chemosis is characterized by a uniform transparent thickening of the conjunctiva, principally of the ball. It is of a pale-pink or yellow color, in contradistinction to the deep red of the blood effusion of ecchymosis. The subconjunctival tissue stopping short at the base of the cornea, the spread of the effusion is arrested there and rises up around it like a mound, with the cornea at the bottom, whence its name. The swelling following the bite of an insect or a bee-sting is a typical form of this affection.

There is also an edema called "filtration chemosis," which comes from the oozing of the aqueous humor from the anterior chamber through a small opening at the sclero-corneal margin. The chemosis which attends upon inflammation is sometimes called "inflammatory edema," to distinguish it from the forms not dependent upon hyperemia or congestion.

Since it is usually symptomatic, there is, as a rule, no call for treatment directly to the condition itself. Occasionally, however, the swelling is so excessive as to endanger the nutrition of the cornea by its pressure, and it is then necessary to evacuate the liquid by puncturing the conjunctiva. This may be done under cocaine by a needle or by making a number of small cuts with the scissors.

To facilitate the absorption of the fluid, compresses of lead and laudanum or hot boric acid may be used. (Burnett.)

Severe edema of the conjunctiva is sometimes a symptom of pyemia, being dependent on a thrombus in the cavernous or ophthalmic sinus (Tait). Chemosis of the conjunctiva following the use of iodide of potassium has been reported by de Schweinitz, and it may succeed a general outbreak of urticaria.—(C. P. S.)

Conjunctiva, Circumcorneal hypertrophy of the. SPRING CATARRAH. This rather uncommon disease of the conjunctiva was first mentioned by Alt in 1854. See **Conjunctivitis, Vernal.**

Conjunctiva, Colloid bodies in the. HYALINE DEGENERATION OF THE CONJUNCTIVA. AMYLOID DEGENERATION OF THE CONJUNCTIVA. See **Conjunctiva, Amyloid degeneration of the,** also **Conjunctiva, Plasmoma of the.**

Conjunctiva, Coloration of the. See **Conjunctiva, Argyriasis of the.**

Conjunctiva, Congenital abnormalities of the. The conjunctiva may be the seat of certain congenital growths. The most frequent of these are the dermoid tumors, which may be partly conjunctival and partly corneal. Subconjunctival fatty growths are very similar to these dermoids in structure and are sometimes associated with them. They are usually found in the outer angle of the upper cul-de-sac. They may be large enough to project into the palpebral fissure.

Microscopically, the epithelium over them is thick and laminated, and the mass itself is composed of fibrous and fatty tissue.

Pigmented patches similar to the moles of the skin are occasionally met with in the conjunctiva; most often in persons who have multiple moles on the face. They must be distinguished from the congenital pigmentation of the sclerotic which is so frequent in some animals that it may be considered the normal condition, and in man is not an uncommon abnormality about the seat of the anterior perforating arteries.

Other forms of congenital growths in the conjunctiva are nævi, vascular and lymphatic, and tumors composed of well-developed bone-tissue, which belong to the class of teratomata; they are usually situated beneath the conjunctiva, between the outer margin of the cornea and the external canthus. See **Congenital anomalies of the eye.**

Conjunctiva, Contusion of the. This may be followed by injection and infiltration of this membrane, rupture of the conjunctival vessels, subconjunctival ecchymosis, and laceration of tissue. See, also, **Conjunctiva, Injuries of the.**

Conjunctiva corneæ. (L.) The layer of epithelial cells covering the anterior surface of the cornea. This in many respects resembles the epidermis of the general surface of the body, being stratified in from six to eight layers, and rapidly renewed from the basement layer. It is somewhat thicker at the periphery than at the centre. Leber thinks that it has an important office in preventing the diffusion of tears into the general substance of the cornea. It is quite soft, and easily removed by knife or needle. In reptiles, that shed their skin entire, this epithelium is cast off with the external cuticle.—(C. P. S.)

Conjunctiva, Cysticercus under the. The *cysticercus cellulosæ,* a hydatid whose habitat is the intermuscular connective tissue of the pig, is occasionally found under the conjunctiva. See **Conjunctiva, Tumors of the.**

Conjunctiva, Cysts of the. These may be readily distinguished by their circumscribed round form, and their pink, translucent appearance, the transparency of their contents being easily recognized with oblique illumination. They may occur in different portions of the conjunctiva and vary in size from a small pea to that of a hazel nut, or even larger. If they extend into the orbit, and attain a considerable size they cause more or less protrusion of the eyeball. The walls of the smaller cysts are generally very thin, and only so slightly connected with the conjunctiva that they may be very readily removed.

Simple serous cysts of the conjunctiva are not common, and are not all of the same origin. Some follow traumatisms, others, no doubt, are congenital.

J. Bistis (*Arch. f. Aug.*, 70, p. 283) gives a very good review on the cysts of the conjunctiva and reports the clinical history and histological condition of an epithelial cyst which developed in the proliferation at the limbus in spring catarrh. It occurred in a boy aged eleven years, who was said to have suffered from his right eye for two years. Five mm. from the upper temporal limbus a yellowish tumor the size of a pea was situated, elastic, easily movable over the sclera, and not painful. The conjunctiva was partly adherent to it. According to the parents, the tumor was formerly smaller and the eye red. When seen there was no inflammation of the tarsal and ocular conjunctiva. The cyst was extirpated. After incision a yellowish fluid oozed.

It was unilocular, its wall was wavy and consisted of dense connective tissue lined with stratified pavement epithelium. The conjunctiva was infiltrated and contained numerous blood vessels. At one point of the conjunctival surface a proliferation of the epithelium extended into the depth with folding of the conjunctiva, a result of a former inflammation, which was also indicated by the infiltration of the conjunctiva with leucocytes. With the development of the proliferation into folds, a gland-like growth was formed, the obstruction of which led to accumulation of secretions and the development of the cyst. By its stratified epithelial lining, it was characterized as an epithelial cyst of the ocular conjunctiva, differing from the lymphcysts which show only one layer of epithelium.

Bernard Samuels (*Arch. Ophth.*, January, 1913, XLII, 12), describes a case of subconjunctival cyst, occurring after removal of a corneal staphyloma. Three years after the removal of the staphyloma examination showed a cyst of the orbit occupying an area larger than the normal eyeball. Operation showed the cyst to be filled with a clear fluid and enclosing within its walls the shrunken eyeball. The cyst was an implantation cyst and had spread posteriorly to the optic nerve, invading the entire space of Tenon.—(C. P. S.) See, also, **Conjunctiva, Tumors of the,** and **Conjunctival cyst.**

Conjunctiva, Dermoid tumors of the. Tumors of the conjunctiva, the histological elements of which resemble skin. Van Duyse has reported a case of dermo-epithelial tumor of the conjunctiva situated some distance from the corneal border, in a child of four and a half years. It was confined to the epithelial layer, the substantia propria being intact. It was composed of epithelial cells arranged in alveoli. It was not considered malignant. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Development of the. The conjunctiva is merely a slightly differentiated ectoderm. Early in embryonic life, ectodermal folds appear above and below the optic cup. These proliferate toward a common center and there fuse, forming the lids. This results in the formation of an ectodermal sac between the lids and the optic germ-cells which gradually develops into the conjunctival sac.—(H. S. G.)

Conjunctiva, Ecchymosis of the. Hemorrhage of the conjunctiva. Rupture of a blood-vessel of the conjunctiva is followed by an extravasation of blood in and under its tissue. On account of the looseness of the conjunctival and subconjunctival tissue the effusion generally spreads, even though in the beginning it is circumscribed, and sometimes may even cover the whole anterior surface of the eye-ball except the cornea. At first the color is deep-red, but as absorption goes on it becomes more yellowish, and finally disappears altogether, leaving behind no mark. The cause of the breaking of a vessel may be a traumatism of some kind, as a blow. It follows often upon some effort during which the blood is forced to the head, as straining at stool, hard vomiting, coughing, etc. It may be caused even by violent rubbing of the eyes. It is very common in children suffering with whooping-cough, and is frequently seen among the aged and those whose vascular walls are weakened from any cause, and may indicate a general atheromatous condition of the blood-vessels.

The ecchymoses which appear in the conjunctiva after injuries to the head not involving the eyes, indicate the possibility of a fracture at the base of the skull.

When the extravasation is fresh it is sometimes possible to express some of the blood through small incisions in the conjunctiva. Usually however it must be left to the absorptive powers of nature. This may be assisted by an application of the lead and opium solution, hot boric acid solution, and mild massage through the closed lids. —(C. P. S.) See, also, **Conjunctiva, Chemosis of the.**

Conjunctiva, Edema of the. See **Conjunctiva, Chemosis of the.**

Conjunctiva, Elastoma of the. Alt has reported (*Amer. Jour. Ophth.*, xxviii, p. 214, 1911) a case of this rare tumor—a pure elastoma of the conjunctiva. In appearance it was a whitish, pearly-looking, small, lobulated tumor, situated about three millimetres from the temporal side of the cornea in the bulbar conjunctiva. It was five millimetres long and about one and a half millimetres wide. There was a slight amount of injection in the conjunctiva surrounding it. The patient complained of a painful sensation which never left the eye. The tumor was slightly movable with the conjunctiva. After removal, the wound

was thoroughly cauterized and it healed smoothly. There has been no sign of recurrence.

On section the whole tumor was found to be made up of fibrous tissue covered by the somewhat thickened conjunctival epithelium. On staining with orcein the whole tumor was found to consist of elastic fibres. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Emphysema of the. The appearance of air under the conjunctiva indicates a communication between the subconjunctival tissue and some one of the pneumatic cavities around the orbit, and is usually the result of traumatism. This traumatism may have ruptured the bony walls which divide the contents of the orbit from the nasal cavity, the frontal sinus, or the ethmoidal cells, thus allowing the air from them to enter and diffuse itself through the loose tissue of the orbit, the lids, and the subconjunctival space. It may also follow ulcerative destruction of these bones leading to an opening in their walls. It is nearly always noticed immediately after a blowing of the nose. The feeling of crepitation under the finger makes a mistake in diagnosis impossible.

A compressive bandage is the only treatment required for the relief of the condition itself. The patient should be cautioned against blowing the nose violently.—(C. P. S.)

Conjunctiva, Epithelioma of the. Epithelioma does not occur as a primary disease in the conjunctiva, but generally extends from the eye lids. It appears as a small, smooth, or slightly nodulated excrescence or button, at the edge of the cornea, and often bears a very striking resemblance to a pustule or phlyctenula. It is distinguished from the latter, however, by the absence of all inflammatory chemosis and irritation, and arterial injection, only a few dilated, tortuous veins converging toward the little tumor; there is often also some serous infiltration. Subsequently the tumor increases in size, and assumes a redder tint, and its surfaces become more nodulated (cauliflower excrescences), being covered by dry thickened epithelium; or there may be a breach of surface, and a thin muco-purulent discharge exudes from the ulcer. The tumor may invade the cornea to a considerable extent, but is generally but slightly adherent to it, so that it may be nearly entirely removed. It may, however, produce a dense opacity of the cornea beyond the limits of the tumor, or lead to deep and extensive ulceration, or even perforation. If the tumor is stalked, it may be freely movable upon the surface of the cornea.

Like all cancerous growths, it should be removed at the earliest possible period, and the edges of the conjunctival wound should be closed with fine sutures, in order that the sclerotic may not be exposed.

It is, however, very apt quickly to recur, when the operation should be repeated without loss of time. But if the tumor has invaded the cornea to any considerable extent, is intimately connected with its tissue, and has greatly impaired the sight, it will be better to remove the eye; but even this does not always guard against recurrence, the new growth springing from the lids, or from the bottom of the orbit. In such cases, it is therefore always advisable to apply the chloride of zinc paste to the orbit, after the removal of the lids.

After describing two cases of this neoplasm, affecting the bulbar conjunctiva, Delord and Revel (*Annales d'Oculistique,* Dec., 1909) express their conclusions as follows: 1. The Malpighian epithelioma of the bulbar conjunctiva generally grows at the expense of this conjunctiva between the cornea and the inner angle of the eye. 2. Its greatest development is in the region of the sclero-corneal limbus but it can increase and develop around the fibrous ball of the eye. 3. In the latter case, the ball resists the penetration of the cancer into the interior of the eye, and, therefore, the epithelioma may be considered relatively benign. 4. It is always proper to be most careful in the exact diagnosis of these lesions and in their prognosis, the infiltrated part of the limbus having already served as a port of entrance for the cancer. 5. The sclero-corneal limbus is, in fact, the defect in the armor established by the union of the cornea and sclera with each other. It is through this region that epithelioma of the conjunctiva passes from the exterior into the interior of the eye, due to the lymphatic vessels that it contains. 6. The treatment should be abscission followed by grattage when the cancer rests only upon the sclera; but whenever the limbus is attacked, it is more prudent to resort to enucleation.—(C. P. S.) See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Erythema of the. Several cases have been recorded in which, during an attack of erythema multiforme, large papillary, and in some instances vesicular, elevations developed on the ocular conjunctiva, usually on the nasal part. They give rise to very few subjective symptoms, are generally bilateral, and disappear in the course of a week or ten days, leaving the tissues unaltered in appearance.

Conjunctiva, Essential atrophy of the. See **Conjunctiva, Pemphigus of the.**

Conjunctiva, Essential shrinking of the. Pemphigus of the conjunctiva. The development of the bullæ of pemphigus on mucous membranes other than the conjunctiva is well known. They are common in the mouth and pharynx; they do not, however, exert so baneful an influence there as in the conjunctiva, and although a

certain amount of contraction of the buccal mucous membrane may result, with the formation of band-like adhesions, the disease is not followed by the very extensive shrinking of tissue and destruction of its secretory powers that is seen when the conjunctiva is attacked. The very different result (as regards scarring) of pemphigus when affecting the skin and when involving mucous membranes is noteworthy. See **Conjunctiva, Pemphigus of the.**

Conjunctiva, Exuberant granulations of the. "PROUD FLESH." Galvanocautery and probably electrolysis are useful in this condition, especially in tuberculosis (or lupus) of the conjunctiva, the lids, the tear-passages, and the nose. A permanent cure may be obtained by treating these cases thoroughly and persistently, as they are local affections at least for a long time.

Conjunctiva, Filaria inemis grassi in the. This is a parasite that is frequently found in the horse and ass. It has been observed up to the present time (Salzmann) in only three cases in man, in Italy. In Addario's case it was located in a tumor about the size of a pea in the conjunctiva. In the case reported by Pace it was situated in the subcutaneous tissue of the eye-lid. No details of the third case are given. The worm may attain a length of nine centimetres or more. See **Parasites of the human eye.**

Conjunctiva, Filaria loa in the. This worm, which is usually from thirty to forty millimetres long, has been known for almost a century. It has an unarmed mouth, and looks not unlike a fine violin-string. It is found under the conjunctiva of the negroes of the west coast of Africa from the Gold Coast to Angola (5° north to 10° south latitude). The free motility of the worm is very striking. It wanders in all directions under the conjunctiva, and not infrequently from one eye to the other, across the bridge of the nose. It may also appear under the skin in other parts of the body. Warmth tends to bring it to the surface. Under the influence of cold it disappears without a trace in the deeper tissues. In the latter situation it gives rise to no annoyance. It is only when it appears under the conjunctiva that the eye is made to water and to become injected. The life of the parasite extends over several years. It finally disappears spontaneously without any unpleasant after-effects.

We know, says Salzmann, but little of the natural history of the filaria loa. The filaria diurna that by day is found in the same places in great numbers in the blood of the negroes is supposed to be the embryo of the filaria loa. It is believed that these embryos are sucked up with the blood of the negroes by the mosquitoes, that

they undergo further development in these intermediate hosts, and are then deposited in the water with their eggs. Water contaminated in this way may cause reinfection in man. Infection by the loa would have little significance in our latitudes were it not that recently white men who have visited that part of Africa have contracted the disease (Robertson, Saemisch, Barrel). The present increased activity in African colonization will doubtless make the loa better known in Europe. Its acclimatization is, however, not to be feared, since the conditions favoring its propagation are present only in the circumscribed area of its normal habitat. The removal of the parasite is easily accomplished by incising the connective tissue. Care must, nevertheless, be observed to hold the worm fast by digital pressure or with a forceps, as it will otherwise quickly escape. It is difficult to avoid injuring so frail a creature during its extraction. This, however, is attended by no untoward results. As a prophylactic measure, sterilization of drinking water is most urgently to be recommended. See **Parasites of the human eye**; also, **Filaria loa.**

Conjunctiva, Filtration chemosis of the. This form of edema is that which comes from the oozing of the aqueous humor from the anterior chamber through a small opening at the sclero-corneal margin. See **Conjunctiva, Chemosis of the.**

Conjunctiva, Foreign bodies in the. In all cases of rather sudden pain and irritation of a single eye, careful examination should be made for the presence of a foreign body. Particles of dust, bits of cinder, coal, etc., cause great irritation when they lodge in the conjunctiva. When found on the conjunctiva it can generally be removed without much difficulty, but frequently it is embedded so deeply as to require digging out with a needle or spud. Gun powder is very commonly found in the conjunctiva. When an explosion of powder near the face occurs, the conjunctiva seldom escapes; and not infrequently the grains pass through this membrane and lodge in the sclera. If allowed to remain they usually set up a considerable amount of inflammation, which results in the formation of a small abscess around them, leading finally to their expulsion. The best plan of treatment is to carefully pick out, under cocaine, all the large grains, douching the surface for a long time with a strong jet of aseptic liquid to dissolve the powder grain and force it out. As a rule all will disappear in time leaving no disfiguring mark.

Very rarely the chestnut or other burr falls into the eye and leaves some of the spines sticking in the conjunctiva. These are sometimes very difficult to find on account of their light color and semi-trans-

parency, and on this account are more dangerous than other foreign bodies, because of their tendency to wander into the adjoining tissues.

Comparatively large bodies occasionally find their way into the retrotarsal folds, especially the upper one, and may remain there for a long time without causing any pronounced trouble. "Crab's eye" or "eye stones" and flaxseed put into the eye for the purpose of chasing out foreign bodies are sometimes found there long after their introduction has been forgotten.

The hairs of certain caterpillars (*Bombyx pini, B. rubi*) occasionally find their way into the conjunctiva and sometimes into the cornea as well, and give rise to a peculiar pathological condition known as *ophthalmia nodosa*. When it affects the conjunctiva it is characterized by great irritation and pronounced inflammation, with the development of small, firm, gray nodules in the substance of the conjunctival tissue. These nodules show a structure containing giant cells like tubercle and in the centre a hair of the insect. The trouble is seldom limited to the conjunctiva, however; the cornea, ciliary body, iris, and choroid are commonly involved in time, and very serious results may follow. These latter manifestations are due to the migration of the hairs. The pathology is somewhat obscure, but it is most probable that the inflammation is due to some chemical irritant in the hair, and that it is not simply a mechanical process. The appropriate treatment is the removal of the nodules as soon as they are discovered and combating the accompanying inflammatory symptoms (Burnett). See, also, **Injuries of the eye.**

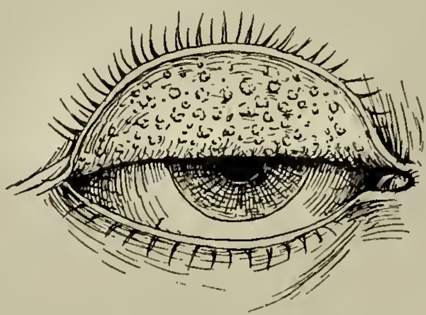
Conjunctiva, Fornix of the. The conjunctiva is continuous with the epidermis at the edges of the lids, lining their deeper surfaces, being thence reflected on the eye-ball. The place of reflection is called the fornix of the conjunctiva. When the eye is open the fornix is about thirteen millimetres from the edge of the upper lid, while it is but nine millimetres from the lower lid. It is five millimetres from the orbital rim above, six millimetres below, and four millimetres at the lateral angle. Its distance from the cornea is estimated by Testut to be ten millimetres above, eight millimetres below, fourteen millimetres at the lateral angle, and seven millimetres at the medial angle. It doubtless varies greatly with the prominence of the eyes. See, also, **Anatomy of the human eye.**

Conjunctiva, Granulation of the. That condition of the conjunctiva characterized by a granular or uneven appearance of the surface. "Granular lids" is not, from a clinical point of view, a single disease. There are at least two broad general divisions which can very well be studied independently as regards their clinical manifestations and

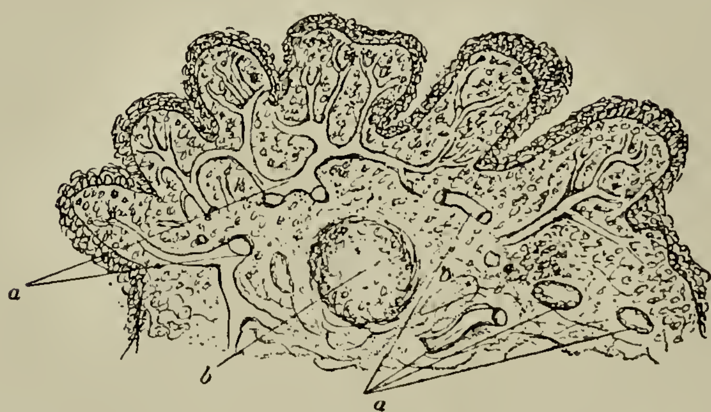
treatment. These are simple granular or follicular conjunctivitis, and trachoma.

In simple granular conjunctivitis the surface of the palpebral conjunctiva is covered over with granules, varying in size from that of a rape-seed to the point of a pin, evenly distributed, and usually in rows parallel to the edge of the lid (see figure). They are reddish or yellowish in color, and the conjunctiva beneath them may be thickened, but is soft and pliable. They are simply the enlarged or hypertrophied normal papillæ or follicles of the membrane (see figure). They are sometimes the result of a long-continued, though it may be low and mild, form of inflammation or simple congestion of the parts. The condition is also called *hypertrophied papillæ*. It frequently remains as a sequel of a purulent or muco-purulent conjunctivitis, but often the beginning is difficult or even impossible to fix. In its simplest form, it is considered by Stephenson as the manifestation of an adenoid activity, and to that extent physiological. It was present in seventy-five per cent. of school-children examined by him. When pathological, the hypertrophy is due to an ordinary inflammatory exudation and enlargement of the normal papillæ, so that the inflammation may persist for a long time and yet there will be no tendency to a destructive process. "It never runs into trachoma." The accompanying symptoms are those of chronic congestion or of catarrhal or purulent conjunctivitis, according as the one or the other process in the conjunctiva is the more active. The cornea is not usually involved, and the bulbar conjunctiva may remain clear unless there is some other irritating condition present. There is a feeling of discomfort in the eyes, especially when trying to use them; a heaviness of the lids, and if there is much secretion the edges of the lids will be gummed together on awakening in the morning. This condition may exist with a true trachoma, constituting a *mixed* form. The therapeutic indication is to reduce the hypertrophy by an absorption of the inflammatory product. This can be best accomplished by the local use of some of the various irritant astringents. Sulphate of copper is one of most efficacious of these. The smooth crystal rubbed over the exposed surface of the everted conjunctiva, and the excess washed off with water. This can be repeated according to the effect desired. An escharotic or destructive action is not desired, but only a temporary hyperemia which will improve the nutrition of the parts and stimulate the absorbents. The application should not ordinarily be repeated oftener than every other day, and in mild cases only once or twice a week. Zinc sulphate gr. ii to the ounce used as a collyrium twice a day may suffice in mild cases. Alum is milder than the copper in its

action, and may be used instead of the latter in mild cases. When any considerable amount of secretion is present, a one per cent. solution of silver nitrate may be applied, but only for a limited time on account of the danger of staining the conjunctiva if used too long. It is necessary to use every care to protect the eyes from strong light, dust and vitiated air of any kind. Any existing ametropia should be corrected by proper-fitting glasses, and the nasal and pharyngeal membranes should be put into as nearly normal condition as possible.



Follicular Conjunctivitis, with no Thickening of the Conjunctiva.



Follicular Conjunctivitis, Showing the Enlarged Papillæ, with their Vascular Supply, a a. (Raehlmann.)

In cases where the swelling of the papillæ is considerable, and the condition has become chronic, Burnett advised the mechanical treatment of "squeezing" with previous slight scarification, as this will more rapidly unload the tissues of inflammatory material which would be absorbed only with difficulty and after a long time.—(C. P. S.) See **Conjunctivitis, Follicular**; also, **Trachoma.**

Conjunctiva, Grattage of the. Grattage is a term adopted by the French to describe a number of related procedures in which the trachomatous conjunctiva is scraped or curetted. The means employed for effecting this result are various. According to Beard "scraping"

is the most ancient of any of the surgical methods. At the end of the eighteenth century, Woolhouse of England, "scraped" granular lids with a little brush made of barbs of grain. Borelli rubbed out the follicles with a brush made of fine metal wire. Strouse, a recent advocate of the operation, uses a specially constructed curette, with a cutting edge 1.5 mm. wide, ground sharp in its entire circumference. The lower lid is everted and rapidly scraped over its entire extent. The upper lid is everted and held between the thumb and finger of one hand, while the curette is passed up into the fornix and this part of the conjunctival sac is scraped, care being taken to penetrate all the folds. The everted portion of the lid is treated last. During the entire procedure, which occupies but a few minutes, an assistant mops the lids with absorbent cotton dipped in bichloride solution 1 to 10,000. The surfaces are washed, and touched, with a 2 per cent. solution of nitrate of silver. Ice pads for half an hour. Strouse states that the advantages of grattage are an uncomplicated technique, rapidity of performance, comparative painlessness, minimum injury to the tissues, absence of inflammatory reaction after operation, simplicity of after-treatment, and absence of recurrences.

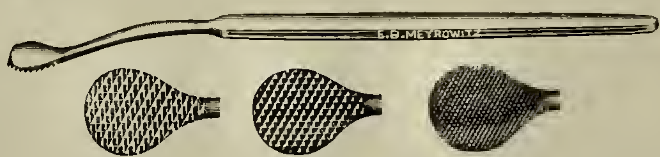
Egbert has devised two curettes, one sharp and one blunt, which are so constructed that all portions of the involved conjunctiva, including the superior fornix and retrotarsal folds can be reached, and the edge is so fashioned that while all granular and hyperplastic material can be removed, there is little danger of injuring smooth healthy tissue. The edge of the sharp instrument points downward and backward to an angle of about 45°, and when the instrument is drawn by the handle, readily engages and removes the abnormal tissue. On the sides of the spoon the edge merges into the flat metal so as to prevent side cutting or laceration. In using these curettes the upper lid is everted over a horn or metal spatula and the sharp curette, the handle of which is held between the thumb and the first and second fingers, much as an ordinary spoon is held, with edge forward, is pushed over the eye-ball well up in the superior cul-de-sac and then drawn downward from all directions of a segment of a circle, similar to that outlined by the brow. Firm though gentle pressure is necessary, and the curetting must be thoroughly done. The blunt curette is now substituted for the sharp one and the process repeated with slightly more pressure until the tissues feel smooth under the instrument. The upturned portion of the conjunctiva is next similarly treated, the edge of the curette being turned downward. The lower lid is then likewise freed from all granules.

A highly ingenious and effective instrument for grattage is the

so-called "trachomatome" devised by Jameson. This instrument is planned on an observation that a pyramid of steel when placed with its apex against a mucous membrane susceptible of indentation and passed to and fro with moderate pressure, will not merge in it but glide over it, producing undulations. This fact applies also to numerous pyramids as represented in the instrument. (See figure.) This is not the case, however, should the membrane be interspersed with elevations such as exist in trachomatous membrane. As the instrument passes over the surface there is a sense of resistance and on inspection it will be found that the trachoma bodies have been attacked and ruptured, the interstices and normal tissues remaining, for the most part, intact. Jameson is confident that this instrument possesses distinct points of utility as follows:

(1) For grattage it places within reach of the operator a graded system of instruments (there are three in the set) adapted to the size of the granules or excrescences to be encountered.

(2) It is an instrument selective of granulation elements and per contra, one which preserves to the greatest degree normal tissue.



Jameson's Trachomatome.

(3) It is adapted not only to the primary operative, but in the postoperative treatment, in the course of which secondary growths may appear.

(4) As an adjunct to the expression operation it opens avenues in affected tissues, rendering expression easy and accomplishing it with less trauma.

A method of grattage and one which bids fair to enjoy extended popularity by reason of its simplicity has recently been described by Coover. Under general anesthesia, the upper lid is grasped by Darier's forceps and turned to bring the retrotarsal fold into view. A horn speculum is introduced beneath the lid to protect the cornea. O or OO sand-paper, in strips three to four inches in length by three-quarters of an inch in width, previously sterilized by soaking in alcohol and burning it off, is rolled lengthwise over the index finger. Holding it firmly between the finger and thumb, the entire lid surface is thoroughly and briskly rubbed. By folding or rolling the strip of paper in different ways all the recesses can be reached and the entire surface rubbed down smooth. If the lower lid is involved, it should be treated in exactly the same way. If there are any granulations on the bulbar

conjunctiva, the operator need not hesitate to smooth them down also, of course using care and more gentle pressure. The surface of the lids and the entire conjunctival sac are now thoroughly cleansed of blood and adventitious sand particles. A moist dressing is applied and held in place by a light yet firm bandage. Cold applications are used for the next five or six hours and the eyes cleansed at intervals. The following day the conjunctiva will be found to be covered with a slight exudate which remains several days. Silver nitrate, two grains to the ounce is applied once in twenty-four hours, to the everted lids. After the exudate has disappeared one per cent. ichthyol in vaseline is used once daily, or 1 to 500 solution copper sulphate is used until the induration or thickness has disappeared, which it does in from three to four weeks.

The advantages claimed for this operation are: (1) That it is applicable to all forms of trachoma. Even in old cicatricial forms it acts beautifully, smoothing down the rough and hypertrophied portions of the conjunctiva. (2) There is very little reaction. In no cases operated on by Coover has there been a severe irritation or a single corneal complication. By this method the smaller granulations in process of development are removed, and the after-treatment with caustics is unnecessary.—(C. P. S.) See, also, **Trachoma.**

Conjunctiva, Growths of the. See **Conjunctiva, Tumors of the.**

Conjunctiva, Gumma of the. A case of true gumma having its seat on the conjunctiva was reported by Norris and Oliver. Several cases of *mucus patches* on the conjunctiva have been observed during the regular course of the disease in this location. See **Conjunctiva, Syphilis of the.**

Conjunctiva gummosa. (It.) GUMMATOUS CONJUNCTIVITIS. A localized conjunctivitis of plastic type, occasioned by the development of a gummy tumor in the conjunctiva or subconjunctival tissue. These gummy deposits usually occur in the course of the external rectus muscle or between the latter and the superior rectus.

Conjunctiva, Hemangioma of the. An angioma made up of blood vessels, as distinguished from lymphangioma. See **Conjunctiva, Tumors of the.**

Conjunctiva, Hematoma of the. A tumor containing blood, generally effused beneath that membrane. See **Conjunctiva, Tumors of the.**

Conjunctiva, Hemorrhage into the. See **Conjunctiva, Ecchymosis of the.**

Conjunctiva, Herpes of the. One or more of the following symptoms may be present in herpes ophthalmicus: first, swelling and perhaps vesication of the conjunctiva; second, vesicles of the cornea itself,

ulcers, or even sloughing; third, keratitis punctata, or iritis not truly serous (hypopyon is very rare). There may be tenderness over the lachrymal gland, with lachrymation. As a sequel of the corneal involvement nebulæ or troublesome phlyctenules may be left.

. During the active stage of the disease the eye lids are nearly always congested and edematous. In severe cases iritis and destruction of the cornea may occur; in mild ones there are merely ophthalmic irritability and photophobia, with slight congestion.

Conjunctiva, Herpes iris of. This is a rare form of membranous conjunctivitis which pursues a somewhat chronic course, and is usually associated with the characteristic exanthem of herpes iris somewhere on the skin, though this is, however, not always present. The character of the eruption is a central reddened or pigmented area of skin surrounded by a wall of vesicles. The first case of herpes iris of the conjunctiva was reported by Fuchs in 1876. Since then cases have been reported by Hanke, Bergmeister, Nettleship, Manz, H. Knapp, Derby, and others, until up to the present time about twenty cases have been recorded. All of the cases present practically the same clinical picture. In one case Gehrke and Kain isolated a coccus which inoculated upon a rabbit's conjunctiva produced membranes there.

According to Parsons the membrane consists chiefly of a fibrinous network with leucocytes in the meshes. The epithelium is necrotic and separated, remnants of the cells being found in the membrane. The raw surface bleeds when the membrane is removed, as in the true diphtheritic cases. If the membrane is not removed artificially it is raised by the development of granulation tissue, and undergoes hyaline degeneration, being finally cast off. It often develops quickly again, but when healing takes place the granulation tissue is covered with epithelium from the sides in the ordinary manner. In the severer cases the subepithelial tissue also contains fibrinous networks, and the peripheral vessels, as well as being dilated, are often blocked with hyaline thrombi. Extensive necrosis may then occur; the fibrin undergoes hyaline degeneration, no longer staining with fibrin stains, and the same takes place in the connective tissue. Cicatrization results in these cases in permanent scarring. Cases of a typical, chronic membranous conjunctivitis previously reported by Morton, Howe, Silcock and Maynard, Batten, etc., possibly belong to this category.

A case illustrating the severe type of this disease was observed in the Fuchs' clinic in 1912 and reported by Hans Barkan. The patient for more than a year had suffered with photophobia and conjunctivitis, following a first attack of the disease. He had a high temperature and was semi-comatose; with hemorrhagic blebs on the skin, ulcerated

areas of the mouth, and a bloody urethral discharge. The eyes showed a severe conjunctivitis of the diphtheritic type, and later a superficial ulceration of both corneæ, and numerous symblephara. There was a constant discharge of great quantities of thick, grayish-yellow secretion. Vision reduced in the better eye to fingers at 5 mm.

There is also a mild form which shows itself as a catarrhal conjunctivitis and ends in complete recovery; a severe form, to which the above case belongs, and a malignant form which sometimes ends in death. However, involvement of the eye in herpes iris is a rarity. —(C. P. S.)

Conjunctiva, Hyalin degeneration of the. See **Conjunctiva, Plasmoma of the.**

Conjunctiva, Hyperemia of the. CONJUNCTIVAL INJECTION. CONGESTION OF THE CONJUNCTIVA. In slight degrees of inflammation of the conjunctiva, the most noticeable change is the increase in vascularity.

Conjunctival injection must be distinguished from ciliary injection which occurs in deep-seated ocular affections such as iritis, chorioiditis, irido-choroiditis, etc. The points of differentiation between these two forms of hyperemia are as follows:

Ciliary Injection (See figure)	Conjunctival Injection (See figure)
1. Comes from the anterior ciliary vessels.	1. Comes from the posterior conjunctival vessels.
2. Is found in diseases of the iris, ciliary-body, and cornea.	2. Is found in conjunctival diseases.
3. Is immovable when the conjunctiva is moved.	3. Is movable with the conjunctiva when pressure is made with the eye lid intervening.
4. Greatest redness is circumcorneal.	4. The greatest redness is posteriorly in the fornices.
5. Redness lessens toward the fornix.	5. Redness lessens toward the cornea.
6. Is of a pink or lilac color.	6. Color is a brick-red.
7. Is composed of a series of fine, straight vessels radiating from the periphery of the cornea. The individual vessels are not easily recognized.	7. Is composed of coarse, tortuous, superficial vessels whose meshes can be discerned.

In idiopathic cases the symptoms last from a few hours to one or two days. The character of the discharge then begins to change. From having been watery, the quality becomes mucous, or possibly mucopurulent. On awaking in the morning, the lids are gummed together due to a drying on the lashes of the discharge which has oozed from

between the lids during the night. Some flakes of mucus will be found in the lower fornix. In severe cases which take on a more purulent form, small hemorrhages in the conjunctiva are sometimes seen. There is a slight swelling of the lids, and a sense of heaviness without any positive pain. There is usually slight photophobia, un-

Congestion of the Posterior Conjunctival Vessels.

Ciliary Injection.

less the epithelium of the cornea is involved, when the photophobia will be more intense. The secretion varies from a small amount of pure mucus to a quantity of muco-pus which borders on a genuine purulent conjunctivitis, and varies at the different stages of the disease. Vision is impaired, partly from a maceration of the corneal epithelium, and from the adhesion of some of the discharge to the

corneal surface. In severer cases, if the corneal epithelium is affected there is an exaggeration of all the acute symptoms: photophobia, lachrymation, and pain. Many ulcerative conditions of the cornea begin in this way, so that the cornea should always be carefully examined in such cases.

In this stage it is often a question whether it may not be the beginning of an iritis, and the pupillary reaction should always be noted, though even at this stage of iritis the pupil still remains quite active. Oblique examination should be used to see if the presence of a foreign body may not be the exciting cause. A very minute foreign body imbedded in the cornea or conjunctiva may keep up a hyperemic condition of the conjunctiva for days or even weeks. The use of the eyes for even a short time is uncomfortable.

The cause of acute hyperemia, such as from the presence of a foreign body, must be removed, if possible. To assist in the resolution of the abnormal vascularity, rest and protection of the eye must be maintained. In mild forms, when the condition is subacute, cocain can be combined with a weak solution of sodium biborate or other of the milder antiseptics. If a beginning iritis is suspected, atropin should be used, in a one-half to one per cent. solution.

In the early stages the eyes should be cleansed with an aseptic or mild antiseptic solution, among which boric acid, ten grains to one ounce of water, is perhaps the best in acute cases. No attempt should be made at an abortion of the process, and all forms of poulticing should be avoided. The application of tea-leaves to the eye has been a favorite lay remedy for this and other eye diseases. The continued application of such poultices often produces the "tea-leaf eye," which is characterized by a soft, thickened, and macerated condition of the skin about the lids and a matting together of the eye-lashes. Nothing should be applied to the eyes which will prevent the speedy exit of the discharge.

Cloths saturated with lead-water and laudanum, or simply wrung out of cold water, may be laid on the closed lids for their cooling and soothing effect. If the hyperemia is excessive, bathing the eyes frequently in water as hot as it can be borne will have a soothing effect. To prevent gumming of the lids together at night, the eyes should be annointed with vaseline at bed-time. When the secreting stage sets in, the use of the mild astringents should be begun. A few drops of a solution of biborate of sodium, ten grains to the ounce, three or four times a day is useful. Later the more purely astringent remedies, such as sulphate of zinc, two grains to the ounce, night and morning, are indicated. Formalin in 1 to 1000 or 1 to 2000 solutions, every

four hours, even in the early stages is most efficacious. If the secretion is of a markedly purulent character, a weak solution of nitrate of silver, two grains to the ounce, is indicated. This should be applied to the lower cul-de-sac by means of a camel's hair brush three times a day, the interval to be lengthened as the discharge lessens. If the cornea is implicated, atropine should be used in addition to the other remedies. If an ulcer or abrasion of the cornea is present, a lead-lotion is contra-indicated, lest a deposit of lead in the cornea take place.

As the discharge is more or less infectious, the cloths, towels, and other articles used about the eyes of the patient should not be used by others, and as much isolation as practicable should be insisted on. Protective spectacles should be used to protect the eyes from glaring light. Smoking should be prohibited and alcoholics used very sparingly.

For the subacute form in which the diplo-bacillus is the exciting cause, Peters and Morax have found the sulphate of zinc solution almost a specific.—(C. P. S.)

Conjunctiva, Icterus of the. JAUNDICE OF THE CONJUNCTIVA. Among the ocular manifestations of yellow fever, there are first congestive conditions, localized in the conjunctiva, particularly during the first period, and, when intense, passing on to the second period with the characteristics of hemorrhagic icterus.

It was observed by Bérenger-Féraud, after studying cases that occurred in Martinique, that the second period of the disease communicates a greater intensity to all the ocular symptoms. This intensity diminishes with the remission of the fever, but if the conjunctiva becomes obscured and takes the icteric hue, the case presents greater gravity.

Conjunctiva, Incised wounds of the. These are to be treated the same as lacerated wounds of the conjunctiva. See **Injuries of the eye.**

Conjunctiva, Inflammation of the. The conjunctiva is liable to various grades and types of inflammation which have certain symptoms in common, such as photophobia, increased and usually altered secretion, and a changed appearance in the membrane, varying from a general injection of the blood-vessels and slight and velvety opacity, to the development of special pathologic products or the formation of false membrane. The generic term "conjunctivitis" is applicable to this entire group of diseases. See, also, **Conjunctivitis.**

Conjunctiva in hypermetropia. In this type of ametropia in which the eyeball does not possess sufficient static focussing power, the symptoms are plainly, and frequently painfully manifest. In so far as the

conjunctiva is concerned, it is frequently manifested by a thickening and irritation, with both stillicidium and epiphora.

Conjunctiva in hysteria. Very often, in addition to the characteristic symptoms of this condition, there are spasm of the accommodation and a slight degree of ptosis, with lachrymation, and a variable amount of injection of the conjunctiva. Almost all the cases present hemianesthesia with insensibility, and even analgesia of the cornea, the conjunctiva, and the eyelids.

Conjunctiva, Injuries of the. On account of its exposed position, and in spite of the protection of the lids, the conjunctiva of the ball is a frequent subject of traumatic injury. The injury may be of a mechanical or chemical nature. The former may prove injurious by the contact with the conjunctiva, setting up irritation and inflammation, or from the wounding and lacerating this membrane. The presence of a foreign body in the eye generally sets up at once severe symptoms of ciliary irritation. Bits of cinder, coal, large particles of dust, glass, straw, etc., often find lodgement in the conjunctiva, particularly that of the lids. In all cases of rather sudden pain and irritation of a single eye careful examination should be made for the presence of a foreign body, as it sometimes happens that the presence of a foreign body is not even suspected. When found on the conjunctiva it can generally be wiped off with a bit of cotton wound on the end of a match. Only occasionally it is embedded so deeply as to require digging out with a spud or needle. Powder is very frequently found in the conjunctiva. In case of an explosion of powder in the face, the conjunctiva seldom escapes. The grains frequently pass through the conjunctiva and lodge in the sclera. They usually set up a considerable amount of inflammation if allowed to remain, which has the result of forming a small abscess around them, leading finally to their expulsion. In treatment it is usually better to pick out carefully, under cocaine, all the large grains, and douche the surface for a long time and frequently with a strong jet of aseptic liquid. In the course of time all will disappear, leaving as a rule, no disfiguring mark.

In burns from lime, an attempt should be made to saponify the lime by means of oil or fat of some kind. All watery solutions must be avoided. Milk is a good substitute. On account of its greater viscidity, castor oil is better than olive oil; it should be rendered aseptic by heat or by mixing it with boric acid. It should be continued through the entire course of cicatrization and sloughing, and cocain and atropine can be mixed with it as indicated. Careful search of the conjunctiva should be made for any remaining bits of lime or

mortar, as a small particle remaining hidden will keep up a severe inflammation for weeks. The chief aim during the process of cicatrization is to prevent a union between the opposing raw surfaces. For this purpose it has been recommended to wear a thin shield of glass, ivory, rubber, or other thin material between the lid and the ball. This is both painful and difficult to maintain in place; the same end can be attained by breaking up the adhesion twice a day by means of a probe carefully passed between the lid and the ball over the whole extent of burned surface back to the cul-de-sac. If the inflammatory reaction is at any time severe, it should be kept within bounds by the application of cold compresses.

A continued exposure of the eye to the fumes of ammonia will produce a pronounced conjunctivitis and even destruction of the tissue. The cornea, too, may become involved. The after-effects of burns of the conjunctiva by chemical substances are apt to be progressive and may extend to the interior of the eye, causing serious disturbances of nutrition, even cataract. Acids of various kinds may get into the eye and cause burns of the conjunctiva of greater or less severity according to the strength of the solution and its corrosive quality. The mineral acids, nitric, sulphuric, hydrochloric, etc., are the most serious. The eye should be washed out with water or an alkaline solution. The subsequent treatment is the same as that for lime.

Burns from carbolic acid, even undiluted, are not very serious in their consequences, since usually only the epithelium is affected.

If hot water, hot ashes, melted lead and iron, etc., find their way into the eye, the eye should be cocainized and the foreign substances removed as soon as possible, and the treatment above outlined adopted; and burns from strong solutions of corrosive sublimate, nitrate of silver, etc., are to be treated on the same general principles.—C. P. S.) See, also, **Injuries of the eye.**

Conjunctiva in myopia. The conjunctival tissues are frequently injected, and there is congestion in the contiguous parts.

Conjunctiva, Lacerated wounds of the. These do not ordinarily require interference beyond aseptic dressings and bandage, except where they are extensive. It is then necessary to bring the edges of the wound together by means of fine sutures. There is little tendency to excessive suppuration in these cases if they are at once rendered aseptic. See **Injuries of the eye.**

Conjunctival apron, Congenital. The term *Conjunctivalschürze*, conjunctival apron, was devised by Schapringer to describe this rare anomaly of the conjunctival membrane. The appearance on everting

the upper lid is as if the conjunctiva near the fornix had been pinched with a wide forceps, lifted up, and then pressed back upon the tarsal conjunctiva. There is no complete adhesion, because a probe can be passed partly or entirely beneath it.

Schapringer reported eight cases, all of which were from Austria and Russia. Tyson (*Arch. of Ophthal.* page 279, 1913) reported a case also from Austria-Hungary. There was no history of traumatism, operation, or inflamed eyes, and none complained of the malformation.

Schapringer explains the etiology by the fact that during embryonal life the amnion adheres to the layers from which the lids will be formed, and that by pulling in that way, a fold in the future conjunctiva originates. Later the amnion separates from these tissues and the fold remains permanently.—(C. P. S.)

Conjunctival bullæ. Bullous diseases of the eye may mean certain forms of herpes of the conjunctiva or cornea, papular conjunctivitis, or pemphigus of the conjunctiva or cornea, or both. These lesions are described under their proper headings. See **Conjunctiva, Herpes of the,** also **Conjunctiva, Pemphigus of the.**

Conjunctival cyst. A rare form of cyst usually appearing as a sharply-defined, spheroidal or hemispheroidal prominence, about as large as a pea and transparent, occasionally met with near the corneal margin. It is congenital and distinct from the true dermoid cyst.

A classification of conjunctival cysts into the more common forms, lymphatic and glandular; the less frequent variety, cysts by inclusion; and the rare cysts caused by entozoa is furnished by Adolf Alt (*Am. Journal of Ophthal.*, October, 1908).

Lymphatic cysts usually lie on the nasal side of the eyeball in the bulbar conjunctiva between the caruncle and the cornea or in the fornix; they start from lymphangiectasiæ and contain a clear, uncolored fluid in which a considerable number of leucocytes and especially lymphocytes are found. They are movable with the conjunctiva, round or ovoid in shape, rarely become sufficiently large to cause annoyance, and their removal by scissors is very simple.

Glandular cysts are found most frequently in the upper or lower fornix, and rarely in the bulbar conjunctiva. Their size varies, but it is usually larger than that of the lymphatic cysts in the bulbar conjunctiva, because glandular cysts are covered by the lids and are not observed so easily. They are also movable and may be colorless or slightly yellow in appearance. They take their origin from Krause's glands or the so-called Henle's glands, and are probably due to inflammatory affections, perhaps to traumatism, or

possibly they originate from abnormal glands in the conjunctiva. The characteristics of their epithelium are that there are several layers of cells, usually more cylindric near the base, more flattened toward the interior, while the interior of the lymphatic cysts presents an endothelial coat of flat cells occurring usually in one or two layers only.

Conjunctival cysts by inclusion are rare. They are always due to injury or operation and show the same changes which we find wherever live epithelial cells have become enclosed in other tissues.

Papilloma of the conjunctiva, like that of other parts of the body, consists of connective tissue papillæ containing blood-vessels and covered with proliferating epithelium. These tumors present the well-known cauliflower-like arrangement and are not frequent in the conjunctiva. They seem to have a predilection for the nasal side, especially for the plica semilunaris and the caruncle. They are prone to recurrence, and may assume the character of a true epithelioma and grow into the neighboring tissues. See **Conjunctiva, Cysts of the,** also, **Conjunctiva, Tumors of the.**

Conjunctival discharge, Contagiousness of. The discharge from a purulent ophthalmia is highly contagious, but varies in its virulence according to the severity and stage of the disease. It is only slightly so during the earliest stage, and also in chronic cases in which the discharge is thin, watery, and transparent. The contagiousness increases in proportion to the intensity of the affection and the purulent nature of the discharge. Piringer, nearly seventy years ago, demonstrated that the discharge of a severe purulent ophthalmia, if applied to a healthy conjunctiva, may reproduce the disease in from six to twelve hours; that from a moderately severe form, in from twelve to thirty-six hours; the mild, in sixty to seventy; and that from chronic ophthalmia in seventy-two to ninety-six hours. The discharge from purulent ophthalmia does not always reproduce the purulent form but may give rise to catarrhal, granular, or even diphtheritic conjunctivitis, just as the discharge from catarrhal, diphtheritic and acute granular conjunctivitis may reproduce the purulent form.

Healthy eyes are more rapidly and severely affected by the inoculation of contagious matter, than those suffering from vascular forms of keratitis, especially pannus. Repeated inoculation diminishes the contagious power of the discharge. The air is without doubt often a carrier of contagion, especially if many persons suffering from severe purulent ophthalmia are crowded together in one room, and that is perhaps small and ill-ventilated. See, also, **Conjunctivitis, Purulent.**

Conjunctiva, Leprosy of the. A general anesthetic condition of the eye is one of the concomitant symptoms occurring in leprosy. It is due to this anesthesia that frequently traumatisms occur. There are also frequently pterygia apparently due to the same cause (Lopez). The leprous tubercles developing on the conjunctiva have the same character as those developing on the skin, and their point of election is the corneo-scleral junction. The conjunctiva is rarely attacked independently of the other parts of the eye. The cornea is the tissue most frequently and characteristically affected, the conjunctiva being only secondarily involved (Bull and Hansen).

Conjunctival glands. In addition to the simple secretory organs of the conjunctiva, the *cells of Becher,* there are glandular structures peculiar to the conjunctiva. It is disputed whether these are simple tubular glands or not, since they are not easy to distinguish from the conjunctival infoldings which occur upon cutting the tissue. However, most of the so-called tubular glands belong to this class, since the epithelium itself becomes changed by the sinking in or infolding of the conjunctiva. They consist of stratified cylindrical epithelium with small round cells at the bottom, while the cylindrical cells are much longer and better developed. But it can not be doubted that genuine tubular glands are sometimes present.

Henle's glands are found in the tarsus and fornix of the conjunctiva. The epithelium itself consists of two layers, the inner of cylindrical and the outer of round cells. The ducts of the glands as a rule do not run perpendicularly, but bend under the epithelium; it is rarely that dichotomous division is seen. This is found for the most part when the conjunctiva is lacking in well developed papillary bodies, and it occurs more often above than below.

In addition to these simple tubular glands there are complex and tubulo-alveolar glands, for example, *Krause's glands.* There are two other kinds of glands mentioned, *Manz's glands* or the sebaceous glands of the conjunctiva, and a variety of coiled glands of the limbus. Manz's glands, as observed by him in animals, consist of a small, round sac lying immediately under the epithelium, possessing a transparent *membrana propria,* an epithelium of several layers of cylindrical cells, and a narrow neck. They contain epithelial cells, free granules, small round cells and finely granular detritus. Their presence in man was at first verified by certain investigators. Later, it was questioned whether they were really glands, and it was asserted that they were chance appearances, nest-like accumulations of epithelial cells in the meshes of the adenoid tissue of the conjunctiva. In the last few years, however, Russian investigators (Theodorow, Fedorow) have again

recognized them as glands; they found them (usually in pairs) in the conjunctiva of both sides (18-30 in number), as well as in the remaining parts of the conjunctiva, least often near the limbus. Waldeyer likewise believes that they occur in man, but Fuchs says that the conjunctiva scleræ contains no glands. The presence of both these glands is not yet certainly established. *(Encyklopädie der Augenheilkunde.)*

Conjunctival hemorrhage in typhoid. The occurrence of hemorrhage from the conjunctiva tarsi of the upper lid, during the course of typhoid fever, is reported by Layson (*Ophthalmic Record*, July, 1914). The patient had been having severe epistaxis as well as hemorrhage from the bowels. The conjunctival bleeding was capillary and quite profuse. It was controlled by moderate pressure. There was no history of a hemorrhagic diathesis.

Conjunctival injection. Hyperemia of the conjunctiva. By this is meant more especially an injection of the conjunctiva bulbi, a dilatation of the smaller veins and capillaries. There is a superficial network of coarser and finer vessels, which moves with the conjunctiva and which has a bright-red color and permits the individual vessels to be clearly seen. If the hyperemia is really restricted to the vessels of the conjunctiva, the reddening of the eye is not very marked. But owing to the many anastomoses, the episcleral network of vessels is also easily involved. Conjunctival injection is a symptom of the more severe diseases of the conjunctiva, but almost always is associated with the ciliary injection in diseases of the anterior portions of the bulb. See **Conjunctiva, Hyperemia of the.**

Conjunctiva, Lipoma of the. A fatty tumor of the conjunctiva. See **Conjunctiva, Tumors of the.**

Conjunctiva, Lithiasis of the. Chalk deposits in the subconjunctiva. Uratic conjunctivitis. This disease is characterized by a deposit of crystals of uric acid or sodium urate in the acini of the Meibomian glands. The disease is associated with the gouty or rheumatic diathesis. Patients with lithiasis complain of a pricking sensation in the eyes and the feeling of a foreign body under the lids. Examination shows the deposits existing as numerous small concretions of a yellowish-white color. Both the palpebral and bulbar portions of the conjunctiva are hyperemic and the anterior scleral vessels are engorged. The disease is more common in elderly than in young subjects. It is proper to state that Herbert, who has carefully studied the conjunctival changes produced by chronic inflammation, considers "lithiasis," "infarcts of the Meibomian glands," and "mycosis" as cyst-formations sequent to the closing of the epithelial tubules.

The downgrowth of these tubules is found not only in papillary trachoma, but also in all forms of chronic conjunctivitis. The cheesy material found in these cysts results from the accumulation and degeneration of epithelial and wandering cells.

The *treatment* consists in removing the crystallized masses with a cataract-needle under cocain anesthesia. This treatment is to be followed by the use of a boric acid wash locally and the internal administration of the salts of lithia. Attention to the general health is required in these cases. The disease is prone to recurrence.—(J. M. B.) See, also, **Conjunctivitis petrificans.**

Conjunctival mycosis. Liégard and Landrieu (*Annales d'Oculistique,* Vol. 146, p. 418) report a case of conjunctivitis in which a streptothrix was found in the direct smear and also in culture. The patient was a woman aged 62 years, much given to the use of face powder, which may have been the origin of the organism found. She complained of irritation in the right eye of three or four weeks' duration, accompanied by an abundant secretion of muco-pus, and a feeling as of grit under the lids. She had suffered on and off for twelve years, but the present attack was the worst she had experienced. Vision was good. On examination there was a slight marginal blepharitis, the edges of the lids were red and slightly thickened, and the skin at the angles of the eye was red. The caruncle was markedly injected, and of a dark-red tint. On everting the lids the palpebral conjunctiva was very injected, and there was a quantity of muco-pus present. The cornea and lachrymal passages were normal, and a diagnosis of chronic sub-acute conjunctivitis was made.

She was treated with zinc sulphate 1 per cent., nitrate of silver ½ per cent., argyrol and various lotions over a period of about eleven months, without much success, when she eventually died of pulmonary congestion.

During this time smears and cultures were made from the secretion. Smears stained by Gram's method showed: 1. Numerous dots, markedly Gram-positive, resembling the micrococci, some singly, others in thick masses. 2. Long thin bacilli, often in chains of two or three elements. 3. In places, long fine filaments like the mycelium of a fungus, some of which looked like chains of streptococci, others showed clear spaces separated by darkly-stained granules, while some were matted together.

In other preparations lateral filaments were seen, ending in single granules or bunches of granules, darkly-stained, somewhat like spores. Cultures were taken and incubated at 37° C. and at room temperature.

Growth was obtained on several of the media used, and slides when

stained showed filaments and dots very similar in appearance to those seen in the direct smear. The appearance of the colonies on the different media is described.

Pinoy, of the Pasteur Institute, who examined the smears and cultures, found that the organism belonged to the streptothrix group of Cohn. This group they further divided into (1) the doscomyces, which corresponds to Cohn's streptothrix fosterii, and (2) the nocardia, corresponding to the streptothrix bovis.

This micro-organism belonged to this latter group. See, also, **Bacteriology of the eye.**

Conjunctival patches. This special form of conjunctival disease is described by Falchi (*Arch. f. Augenheilk.*, Vol. LXX, part 2, 1911). He followed a case during its entire clinical course, and gives the clinical history, histo-pathologic findings, histo-chemical and bacteriological examinations. On the conjunctiva of the lower lid were small snow-white patches arranged in groups, which later coalesced into large white oval patches. They were located in the tarsal conjunctiva, the fornix, and the lower half of the bulbar conjunctiva. There was no ulceration. The development period of the patches was 8 to 12 days. The stationary period lasted 8 to 20 days. The retrogressive period was about 12 days. Relapses occurred from one to three times a year for 5 years. He gives a differential diagnosis from other forms of conjunctival patches and concludes that the ophthalmia in the form of conjunctival patches differs in clinical appearances, pathogenesis, pathologic, histo-chemic, and bacteriologic findings, from conjunctivitis, pemphigus, syphilis, tuberculosis, ophthalmia nodosa, spring catarrh and Parinaud's conjunctivitis.

The cornea, sclera, uvea, retina and optic nerve, as well as the visual perception, remained normal. No pathogenic connection could be found between the febrile prodromal stage and the development of the conjunctival patches. Ophthalmia in the form of conjunctival patches is caused by degenerative changes of its tissues; in the epithelium covering the patches there is mucous degeneration. There are uncertain evidences of slight amyloid degeneration. There was some fatty degeneration near the Meibomian glands. Some of the mast cells were in a state of degeneration, as well as some of the blood-elements in the vessels and in the connective tissue.

Bacteriological examination showed the presence of staphylococcus albus. Pure cultures of the staphylococcus albus, inoculated into the conjunctiva and cornea of the guinea pig, did not reproduce either the clinical form or the pathological changes of this form of ophthalmia.

Bichloride injections under the patches and subcutaneously had no effect on the condition.

The best treatment for this condition is the following:

In the period of development; instillation into the conjunctival sac of (a) 4 per cent. boric acid solution, or bichloride 1 to 5,000; (b) when there is much photophobia, instillation of 1 per. cent. pilocarpine muriate; (c) permanent bandage; (d) when there is pain in the eye, instillation of cocain or tropoeocain 3½ per cent., and the internal administration of quinine and arsenic.

In the retrogressive stage: continuation of the above mentioned antiseptic instillation, without the bandage.

The operative removal of the patches which are surrounded by other patches is not to be recommended, as this is usually followed by the formation of new patches in the neighborhood. If, however, only one or a few patches exist in an otherwise healthy conjunctiva, the removal of the patch or patches may cure the condition and prevent relapses.

Conjunctival sac. When the eyelids are closed the edges of the palpebral conjunctiva are brought together, the entire membrane forming a closed sac,—the conjunctival sac. See, also, **Anatomy of the human eye.**

Conjunctival sac, Fluid in the healthy and diseased. There occurs according to Schirmer (*Wien. med. Woch.,* May 16, 1908) a greater production of fluid in the conjunctival sac than there is lost by evaporation. In a normal individual when he is awake 0.5-0.75 gm. of tears are produced in 16 hours, of which 0.27 gms. evaporate; 0.003 gms. of tears are pressed through the tear duct into the nose. During sleep the lachrymal gland does not secrete, and the circulation through the lachrymal duct ceases. After extirpation of both lachrymal glands the conjunctiva does not become dry, because the conjunctiva itself produces as much fluid as it loses by evaporation. The eye thus remains in just as moist a condition as normally, and only during crying does the one eye become drier than the other.

Lachrymation in facial paralysis can be explained by the fact that the Horner's portion of the orbicularis cannot contract; nictitation, and with this aspiration through the lachrymal sac, ceases, and the tears are not led into the nose.

Conjunctival sac, Temperature of. The temperature of the conjunctival sac, according to Silex, is 35.55° C. (95.99° F.), i. e., about 2° lower than that of the rectum. There is an average increase of 0.98° C. in inflamed eyes, the highest temperature being found in acute iritis. The temperature of the cornea is about 29° C. (Leber).

Conjunctiva, Lupus of the. The disease described as *lupus conjunctivæ* by the older writers was without doubt the same that we now

recognize as tuberculosis. The clinical distinction that is made at the present day between the two is that in lupus the disease begins in the skin and passes over to the conjunctiva, whereas in tuberculosis the ulceration is primarily of the conjunctiva. See **Conjunctiva, Tuberculosis of the.**

Conjunctival vessels, A microscopic study of the. Luedde, W. H., (*The American Journal of Ophthalmology,* May, 1913), with the aid of a Zeiss binocular corneal microscope, has examined carefully the conjunctival vessels. The most important observation concerns the vascular changes in arterio-sclerosis.

In the later stages of arterio-sclerosis the retinal appearances are quite positive, but even then do not permit an independent and conclusive prognosis concerning the general health of the individual. On the other hand, the changes in the conjunctival vessels are demonstrable as soon as their lumen is encroached upon, making it possible to discover the first symptoms of vascular disease. . Furthermore, the signs are so clear and definite that they can be recognized unhesitatingly by any careful observer.

Evidence obtained from any ocular symptom of arterio-sclerosis is only of relative and corroborative importance. Nevertheless, no clinician can afford to overlook what might be learned by a careful study of ocular conditions, including microscopic investigation of the conjunctival vessels, in any case of vascular disease.

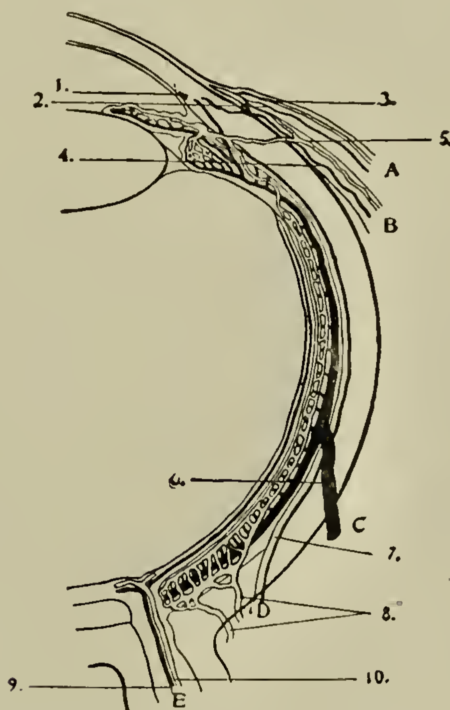
Especially is this true in those cases where the onset is stealthy and obscure, and where an analysis of the general findings and symptoms seems to lead to nowhere. Not infrequently such cases will be found to be the victims of early angio-sclerosis and will clear up after treatment of this condition and its underlying causes.

Conjunctival vessels, Anterior. These are minute vessels which form loops in the peripheral part of the cornea. Hyperemia of these causes a bright red discoloration around and partly in the cornea, and is typically seen in the early stages of interstitial keratitis. See **Anatomy of the human eye.**

Conjunctival vessels, Posterior. These arteries and veins form one of the three systems in the blood-supply of the anterior part of the eye (Nettleship). Hyperemia of these causes a bright-red color, which moves with the conjunctiva. It is associated with a mucopurulent discharge and indicates conjunctivitis. The greatest redness is in the fornices. See, also, **Anatomy of the human eye.**

Conjunctiva, Lymphangioma of the. A dilated or varicose condition or tumor of the lymphatic vessels of the conjunctiva. A. Erb (*Zeitschr. f. Augenheilk.,* Feb., 1913) furnishes the history of a boy, aged 10,

who developed soon after birth, a flat, soft tumor at the right eyebrow, which gradually grew and spread over the selera, in the form of a gelatinous swelling. After a blow on the eye two weeks previously, the white swelling suddenly became dark-red. It was movable with the eonjunctiva. For exact diagnosis, a pieee was exeised and examined at the pathologieal institute at Zürieh, and found to be a hematolymphangioma. The epithelium of the eonjunetiva was intact, the subeonjunetival tissue was thickened and eontained numerous eavities of different sizes, whieh were partly empty, partly filled with a homo-



Vascular Systems of the Eye.

A, Conjunctival vessels. B, Anterior ciliary vessels. C, Vena vorticosa. D, Posterior ciliary arteries. E, Central retinal vessels.

geneous mass, eoagulated lymph, some with blood, and were lined with endothelium. The septa eonsisted of fibers of nuclear eonneetive tissue in which nodules of lymphatie tissue were mingled, partly with fresh inflammatory infiltrations. Sinee, on aeeount of its extent, total extirpation of the tumor was out of the question, it was redueed by electrolysis. When the patient returned after some time, the eye was white and the whole oeular eonjunctiva showed a markedly pale, ehemotie swelling. V with + eyl. 4.00 90° = 5/15. Dionin prodneed an enormous swelling of the conjunetiva, whieh subsided after five days.

With regard to the etiology, Erb adopts the explanation of Ribbert, who assumes processes of proliferation of connective tissue and lymphatic spaces lined with epithelium, starting from a tissue, which was separated during intra- or extra-uterine life.

Conjunctiva, Lymphatics of the. There is a considerable plexus of lymphatics in the conjunctiva, which is in communication with lymph spaces of the cornea. The fluids collected within the corneal spaces are in part carried off by these lymphatics which are the most important channels for the escape of the contents of the intra-corneal lymph-paths. See, also, **Anatomy of the human eye.**

Conjunctiva, Lymphectasia of the. The flow of lymph in the lymph-channels of the conjunctiva sometimes becomes obstructed, causing the walls of the lymphatics to stand out like small transparent beads on the conjunctiva. This is nearly always in the palpebral fissure and about midway between the cornea and one of the canthi, though Hirschberg has reported a case in which the beads made circles around the cornea. Leber reports a case of a woman in which the lymph was periodically mixed with the coloring matter of the blood—lymphectasia menorrhagica.

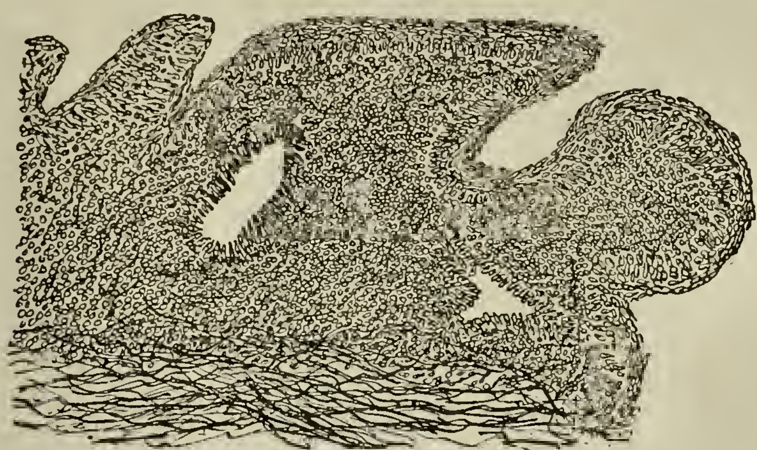
As a rule they give rise to no trouble. They are sometimes congenital. They can be evacuated by pricking each globule with a needle, or the whole may be extirpated if the mass is not large. (Burnett). See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Lymphoma of the. This rare form of conjunctival disease is liable to be confounded with certain stages of trachoma occasionally met with, or with amyloid degeneration. There are many facts indeed, which point to the probability of its being the first step in this latter form of conjunctival degeneration. It seems frequent in certain parts of Europe, especially Russia (Raehlmann). The conjunctiva, generally of the upper lid alone, is enormously thickened, sometimes five to six times the normal, and there is an inability to lift it on account of its weight (ptosis). The conjunctival surface is irregular and traced over with deep sulci, but not pronouncedly granular. It is rather hard and gelatinous-looking, but does not bleed easily on rough handling. It sometimes affects the lower lid and caruncle and retrotarsal folds, usually in the form of large prominent round swellings. There is little or no secretion, the cornea is usually clear and unaffected, and there is commonly no pain complained of. The disease is almost always bilateral. Michel has found the general glandular system to be enlarged. It occurs most frequently in boys of from seven to eighteen years.

Wecker has described a form of the disease which affects the con-

junctiva around the base of the cornea, looking not unlike an exaggerated form of circumcorneal hypertrophy of the conjunctiva. Section of the membrane shows it to be composed of enlarged papillæ with hypertrophy of the adenoid structure, but no amyloid degeneration (see figure). In a case observed by Burnett, there was an extensive colloid degeneration in the deeper portion of the thick mass. The epithelial layer was intact, and in some parts much thickened. The tarsus does not seem to participate in the pathological process, certainly not at the beginning. It is asserted that there is a tendency to improvement after puberty.

The only treatment is operative. In the milder cases deep incisions are recommended by Wecker, but when the thickening is great the only thing to do is to remove the mass with the knife and scissors, or with the curette when there is a colloid degeneration. As



Lymphoma of the Conjunctiva, Showing Enormous Enlargement of the Papillæ, Covered with Epithelium and Dense Infiltration of Adenoid Tissue with Round Cells.

there is usually a diffuse adenitis, the general health requires attention, and removal to a high dry climate is advisable.—(C. P. S.) See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Malignant tumors of the. The conjunctiva may be affected with malignant growths just as in other mucous membranes. Among one hundred and thirty-seven malignant epibulbar growths Noyes in 1879 found seventeen to spring from the conjunctiva and thirty-one from the limbus. Epitheliomata forms by far the largest number of these growths. It is maintained by Panas and others that the so-called sarcomatous forms are really epitheliomata of more rapid growth. True sarcomata of the limbus were reported by Stronse in 1897, most of which started in the conjunctiva, and where the cornea was invaded it was only in the epithelial layers or the layers of the

substantia propria contiguous. (See figures.) The case illustrated below, which was reported by Oliver, is a good example of the epithelioматous form at the sclero-corneal margin. In this case, after several extirpations, the eye finally had to be sacrificed.

The variety of melanotic tumors which have been described owe their pigment to their situation near the uveal tract or to hemorrhage (Panas), and should not be considered on that account as sarcomatous in the true sense. Some cases of what seemed to be true carcinoma have been described as occurring on the conjunctiva. Except when they pass over from the integument of the lid to the conjunctiva, these tumors are most commonly found at the sclero-corneal margin; this situation, as pointed out by Fischer, being the analogue of the predilection of epitheliomata for the boundary between two kinds of epithelium, as the edge of the lips, the anus, etc. The locality of the sclero-corneal margin is very subject, too, to proliferation of epithelium of a benign character. The growth of these tumors is usually slow, but they may attain in time to a large size. They grow by preference in the direction of the cornea, sometimes entirely covering it. They may also extend by ulceration into the interior of the eye at the edge of the cornea. The sclera, on account of its toughness, resists the attacks of the growth much longer than the other tissues of the eye. They affect almost exclusively persons advanced in life, and, like epithelial growths of the face, remain localized and show but little tendency to involve other parts of the body by metastasis.

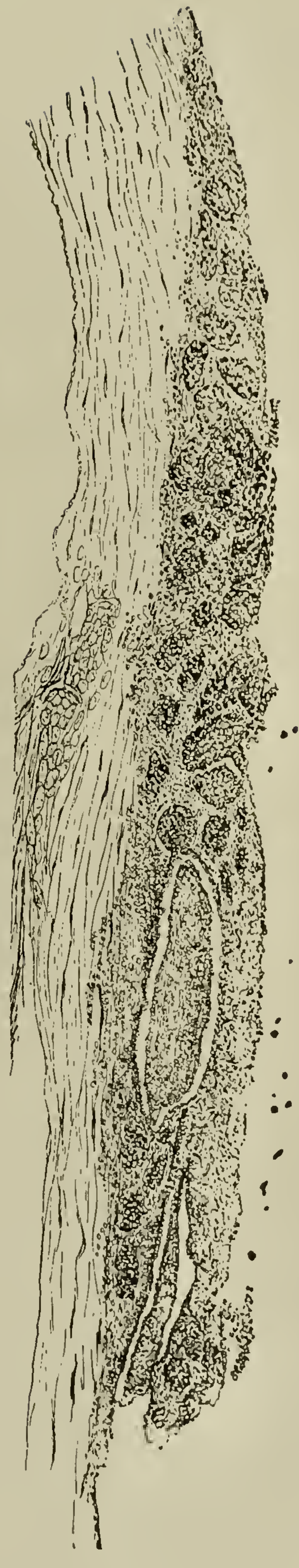
The diagnosis is not usually difficult, particularly after ulceration has begun. Extirpation is the only treatment of malignant or supposed malignant growths. This should be done as early as possible and when the tumor is small, if a recurrence, which happens in a large majority of cases, is to be avoided. When it has attained any considerable size and its removal entails the loss of a large amount of tissue, it is better to sacrifice the eye at once by enucleation. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Medullary cancer of the. This form of growth almost always extends to the conjunctiva from the lids or from the eyeball itself, the cornea or sclerotic giving way, and the tumor sprouting forth and very rapidly spreading thence into the neighboring tissues. See, **Conjunctiva, Malignant tumors of the.**

Conjunctiva, Melanotic cancer of the. This appears in the form of a small darkish-red or brownish-black spot or tumor in the subconjunctival tissue near the cornea, at the semilunar fold or caruncle. As it increases in size it may implicate the lids, extending beneath them and giving rise to more or less considerable adhesions. The

Macroscopic Appearance of the Tumor at the Corneo-scleral Junction. (Oliver.)

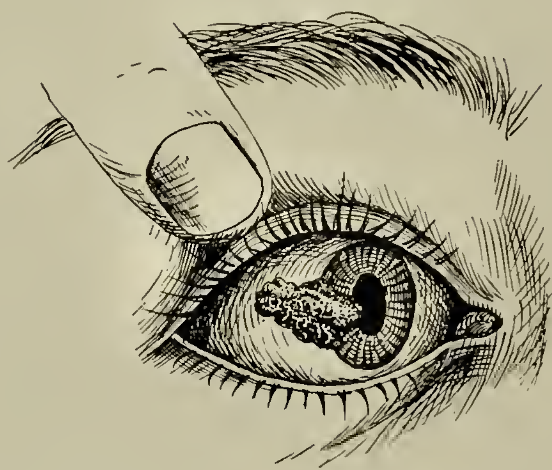
Microscopic Section Showing Infiltration of the Epithelial Cells into the Corneal Lamellæ. (Oliver.)



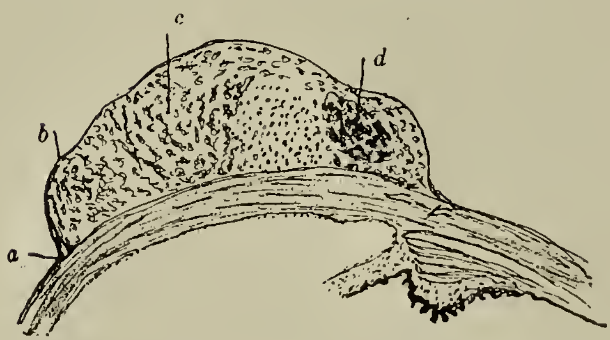
Microscopic Section Showing Position and Extent of the Growth. (Oliver.)

tumor may remain stationary for a long period and then rapidly increase, and it is very prone to recur quickly after removal. It must be remembered, however, that many of the little black tumors which are often erroneously called melanotic cancer are only sarcomata. See, **Conjunctiva, Malignant tumors of the.**

Conjunctiva, Morbid growths of the. The morbid growths which occur in the conjunctiva are those found in mucous membranes in other parts of the body, though some of them have a greater seriousness and significance on account of their situation and proximity to important tissues than they would had they occurred elsewhere. They include both benign and malignant growths, and will be discussed under their appropriate headings. See, **Conjunctiva, Tumors of the.**



Melanotic Epithelioma of the Limbus.



Melanotic Epithelioma of the Limbus.

The growth, starting from the conjunctiva of the limbus, is confined to the epithelium of the cornea: d, a, melanotic spot. (Panas.)

Conjunctiva, Mucous patches on the. There would seem to be no reason why mucous patches should not occur, during the regular course

of syphilis, on the conjunctiva as well as on other mucous surfaces. Several such cases have been reported. See, **Conjunctiva, Syphilis of the,** also **Chancre of the conjunctiva.**

Conjunctiva, Nævi of the. These sometimes extend from the external portion of the eyelid to the palpebral or even the ocular portion of the conjunctiva, and may reach a very considerable size if they are not treated at an early period. They may occur primarily on the conjunctiva or the semilunar fold, and should be removed as early as possible. Small ecchymoses of the conjunctiva may be mistaken for nevi, but these latter, according to Beard, are exceedingly rare, are congenital, and are not given to changes in size.

Jarvorski (*Klin. Monatsbl. f. Augenheilk.*, May-June, 1911) reports a case of nevus occurring in a woman forty-five years of age. It was of a yellowish-red color, beginning at 3 mm. from the inner corneal margin, extending across the cornea beyond the center, making a sharp curve to the lower corneal edge. It varied in width from one to seven mm.

A small piece of the conjunctival nevus was removed and examined histologically. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Nerves of the. These are from the lachrymal and from the supra- and infra-trochlear branches of the nasal. See **Anatomy of the human eye.**

Conjunctiva, Ocular. CONJUNCTIVA OCULI OR BULBI. That portion of the mucous membrane which is reflected upon the eyeball, covering its anterior third. The ocular conjunctiva is distinguished from the palpebral by its less vascular condition and paler tint. It is divided into a scleral portion *(conjunctiva sclerotica)* and a corneal portion *(conjunctiva corneæ)*, which differ somewhat in structure, the scleral being composed of stratified pavement epithelium with a regular submucosa, while the corneal has an epithelial layer only, the submucous tissue blending with the corneal tissue proper, or being reduced to a very delicate structural layer. Near the cornea it is closely adherent to the sclera, often in adults forming a slightly thickened ring containing numerous vascular papillæ and known as the *limbus conjunctivæ.* Fatty deposits (*pingueculæ*) are frequently seen on the medial side of the limbus, especially in old age.

The external part of the scleral conjunctiva is united to the ball by connective tissue partly condensed, a continuation of the bulbar fascia, and in part quite lax, continuous with the adipose capsule of the eye. The laxity of the union of the conjunctiva with its subjacent tissues, both at the fornix and upon the sclera, secures the necessary freedom of movement to the ball. In whatever direction the eye may

be moved the conjunctiva on the opposite side is stretched. At the nasal side, where the fornix lies so near the ball, movement is provided for by an accessory fold (plica semilunaris), a vestige of the third eyelid found in some of the lower animals. The laxity of the tissues beneath the conjunctiva makes it very easy to raise it whenever it is necessary to perform any operations within the orbit. It also explains the frequency of ecchymosis in this situation. Sometimes, indeed, a fracture of the base of the skull or other internal injury causing the rupture of vessels may become known by an ecchymosis of the scleral conjunctiva, the blood gradually infiltrating the looser tissues of the orbit and appearing at last upon the ball.

When fixing the eyeball for the performance of an operation the conjunctiva should be seized near the cornea, where it is more firmly attached.—(C. P. S.) See, also, **Anatomy of the human eye.**

Conjunctiva, Operations on the. In operations upon the conjunctiva the same rules of aseptic procedure must be observed as are applicable to surgery in general. The ophthalmic surgeon realizes that even in minor operations, slight injuries or cicatricial connections may produce inordinate disturbances, such as epiphora, diplopia, etc. The surgical treatment of the various morbid conditions of the conjunctiva will be discussed under their proper headings.

Conjunctiva, Osteoma of the. Osseous or fibro-osseous tumors are found in the conjunctiva in rare instances (Critchett, Snell). Their usual seat is on the ball and near the external commissure. As they are observed mostly in young people, they are probably congenital, of the same nature as dermoids and due to faulty or abnormal development. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva palpebræ. (L.) CONJUNTIVE PALPEBRARUM. PALPEBRAL CONJUNCTIVA. The mucous membrane lining the inner surface of the eyelids, which at the ciliary margin passes insensibly into the cutis of the eyelids. It extends as a lining membrane into the ducts of the Meibomian glands, the lachrymal canaliculi and sac. It is of varying thickness, highly vascular and closely attached to the tarsus of the lid, and contains various glandular structures known as Krause's glands and also papillæ, most marked in the upper lid.

Conjunctiva palpebrarum. (L.) PALPEBRAL CONJUNCTIVA. TARSAL CONJUNCTIVA. Same as **Conjunctiva palpebræ.**

Conjunctiva, Papilloma of the. A form of polypoid growth which is sometimes called *soft fibroma.* It usually has an uneven wart-like surface and a structure similar to that of a condyloma. It usually grows from the caruncle, but is found in the palpebral conjunctiva also.

These growths sometimes become epitheliomatous if neglected, or may be really epitheliomatous from the beginning. In removing

them, it is recommended that careful curetting be done, to lessen the liability to a recurrence. See **Conjunctiva, Tumors of the.**

Conjunctiva, Passive congestion of the. There is in this condition of chronic hyperemia, not so much an increased activity of the arterial circulation as a retarded and sluggish venous return. The veins are increased in size, are more tortuous in their course, and often stand out quite prominently on the conjunctival surface. As a rule, this is much more evident on the palpebral surface than on the bulbar portion of the membrane. In fact, the bulbar conjunctiva in a large number of cases is not at all affected, though it is always liable to flush up or get "blood shot" from trivial causes, such as exposure to cold, smoke, loss of sleep, etc.

While not dangerous, it is very annoying and uncomfortable and sometimes renders any regular use of the eyes impossible. It is one of the most common conjunctival affections, because it is usually symptomatic of or concomitant with many other affections of the eye, the lachrymal apparatus and the upper air passages, and is rarely absent in the eye-strain of ametropia.

Those employed in a dusty or vitiated atmosphere are most often victims of this affection. Aside from these the most common cause is an uncorrected ametropia or disturbed muscle balance, and even when resulting from other causes, it is often kept up by the eye-strain consequent upon these conditions.

The symptoms are usually those of discomfort and annoyance rather than of positive pain. There is a sensation of heat, a burning and itching of the eyes, and a heaviness of the lids, with a tendency to keep them closed, especially in artificial light. There is very commonly a feeling of dryness and stiffness of the lids. It is for this reason that the condition is sometimes called *dry catarrh.* Very frequently too, there is a feeling of sand or grit in the eye, caused by the protrusion of swollen veins, acting as irritable foreign bodies.

If the condition persists for some time it usually leads to more or less pronounced alteration of the parts, which shows itself by a thickening of the papillary structures known as *hypertrophied papillæ.*

On the palpebral portion of the conjunctiva the normal smooth appearance is lost and the surface is covered with very minute dots, as though it had been dusted over with fine meal, much smaller than the granules which appear in follicular conjunctivitis and trachoma. Such a condition of passive congestion of the conjunctiva is a frequent accompaniment of a chronic catarrhal condition of the nasal passage; as a sequel of exanthematous fevers; or as a residuum of some form of acute conjunctivitis. It affects especially those who are employed

in a dusty atmosphere and unhygienic surroundings. A long continued eye strain from an uncorrected ametropia or disturbed muscle balance is a not uncommon cause, and the correction of these conditions by the proper glasses frequently will cause the eye symptoms to disappear promptly and permanently.

The removal of any of these possible causes is the first step in the treatment of this condition. Avoidance of a smoky, dusty or vitiated atmosphere, abstinence from tobacco and alcoholics, the avoidance of glaring light by protecting the eyes with tinted glasses, etc., should all be insisted upon. The general system should be kept in good condition, all abnormalities of the nasal mucous membranes should be corrected as far as possible.

Direct medication of the conjunctiva consists in the application of the milder antiseptics and astringents: boric acid, biborate of sodium, and if a stronger astringent is indicated, a solution of sulphate of zinc, two grains to the ounce, can be employed.

Equal parts of tincture of opium and water form a useful collyrium. Formalin 1 to 2,000 is very acceptable to some patients. In those conditions of dry catarrh where there is no secretion, nitrate of silver is not applicable. This is used to the greatest advantage where there is a succulent condition of the conjunctiva with a discharge of mucus or pus. In very obstinate cases, the direct application of the solid stick of sulphate of copper to the mucous surface of the everted lid produces a profound impression on the vascular walls, the effect to be mitigated by the extent and length of the application, and by washing off the surface thoroughly afterwards with water. This must be repeated every day or two, or weekly, as the case demands. The alum stick can be used in the same way. Spraying of the closed lids with a mixture of water and alcohol or bay-rum, or simply douching of the closed lids with cold water, is very gratifying and soothing. This can be done as frequently as the eyes feel hot and uncomfortable.

In those cases in which there is a faulty systematic elimination, of which gout is a typical representative, there is sometimes observed a tedious form of conjunctivitis, associated nearly always, after a time, with superficial isolated infiltrations of the cornea, and sometimes with involvement of the underlying sclera. There is not usually any considerable mucous secretion. The attacks continue, with recurrences, sometimes for two or three months, and the exacerbations are commonly associated with changes in the weather. A course of mineral waters, as at Carlsbad or Kissingen is usually beneficial.—(C. P. S.) See, also, **Conjunctiva, Hyperemia of the.**

Conjunctiva, Pemphigus of the. Essential atrophy. Degenerative syndesmitis. Essential shrinking of the conjunctiva. Much

difference of opinion has been expressed concerning the relationship between pemphigus and a peculiar intractable and destructive affection of the conjunctiva. The latter has been described as *pemphigus of the conjunctiva* and as *essential shrinking of the conjunctiva.* The difficulties in determining the exact nature of the eye affection are considerable, declares Lawford, because dermatologists are by no means agreed as to the diagnosis between pemphigus of the skin and some other bullous eruptions. The development of the bullæ of pemphigus on mucous membranes other than the conjunctiva is well known. In the mouth and pharynx they are not uncommon. Cases have been reported in which no vesicles were seen on the conjunctiva or elsewhere, but in which the atrophic changes in the conjunctiva and cornea were well marked. Under such circumstances, some observers have reasonably doubted whether the diagnosis of pemphigus was justifiable. It is the prevailing opinion, however, that the term "*pemphigus*" is the correct one to apply to the conjunctival and corneal condition originally described by White-Cooper under this name.

Wilson, Kaposi, and others, show that pemphigus is one of the rare diseases of the skin. It is therefore to be expected that pemphigus of the conjunctiva is uncommon. It may occur at any age. In twenty-eight cases collected by Morris and Roberts, the youngest age was four, and the oldest seventy-six. The ocular affection is usually bilateral, though often unequal in degree in the two eyes. In its tendency to symmetry it contrasts noticeably with the skin lesions. There seems to be no constant relation between the duration of the skin affection and the development of the eye lesions. The bullæ have appeared on the conjunctiva in some instances after only a few weeks from their first appearance on the skin, while in other cases the interval has been months and even years. In about 28 per cent. of the cases collected by Morris, the disease is said to have attacked the conjunctiva primarily, but it is probable that in such cases the cutaneous lesions were overlooked. Careful examination and observation would be of great value in establishing the correctness of this disputed question, as to whether or not cutaneous lesions always precede the ocular complication.

The conjunctival lesions are met with in cases in which the skin affection is chronic, and not severe. According to Lawford, no instances have been recorded of conjunctival lesions in acute pemphigus. The course of the ocular disease, like that of the skin, may be very chronic. Samelsohn observed a case in which bullæ repeatedly developed on the conjunctival surface of the lids during seven years,

and but little atrophy resulted. In other instances, however, a much shorter period sufficed for extensive destruction of tissue. In a case recorded by Silcock, one eye was destroyed within seven weeks after the patient came under observation, and the other was seriously damaged. Suppuration of the cornea has occurred in a few instances, and has led to rapid destruction of the eye.

The bullæ are first noticed on the fornix or bulbar conjunctiva. After a time, which may be months, others appear on the ball and palpebral surface, and the final result is an ulceration leading to a cicatricial shrinkage of the entire conjunctival tissue and an adhesion of the lids to the ball through their whole extent (symblepharon), and sometimes of the edges of the lids themselves (ankyloblepharon). The cornea early begins to lose its polished surface, becomes opaque, and participates in the general atrophy.

The prognosis of pemphigus of the conjunctiva is extremely unfavorable; the morbid process nearly always progresses until sight is entirely destroyed. Two cases of recovery were reported by Samelsohn and one by Marcus Gunn.

Reports of the microscopic examination of the diseased conjunctiva are given by Sattler, Gelpke and Bäumler.

The treatment is entirely palliative. All operative procedures have utterly failed to give relief.

The case of a seventy-year-old Russian was reported by Weidler in 1910. (*Arch. of Ophthal.* xi. p. 283.) The lids were thick and shrunken and a condition of total symblepharon united the lids to the eyeball to the very edge of the lids. The bulbar conjunctiva that was visible was thick and thrown into folds over the cornea. The eye presented the appearance of an old trachomatous process with shrinking. The left eye showed some matting of the lids with secretion. The symblepharon was slight. The conjuntiva was red and swollen with the appearance of edema in places. The corneo-scleral margin showed a number of small bleb-like formations of pearly-white color. Several small whitish areas in the same location bled freely when gently rubbed with an applicator. The symblepharon gradually increased and the opening between the lids became less, until it became impossible, in one eye, to separate them. There was a curious swelling over the upper lid and directly under the skin in the subcutaneous tissues, there was also edema of the upper lid. Later on the bulbar conjunctiva of the left eye showed spots of necrosis which were white and bled profusely on the slightest effort to examine the eye. The conjunctiva was observed to be slowly extending over the cornea. The areas of necrosis, the bleeding, the synechia formations, later the cicatrization and the

contraction and finally the symblepharon describe the character of the progress of the disease. The flow of tears had ceased, and there was a slight ulceration of the upper part of the cornea.

Vision became greatly reduced with the progress of the disease and the general health also declined.

There was no history of syphilis. The blebs of the conjunctiva resembled the lesions sometimes seen in pemphigus of the throat. An examination of the nose revealed a dirty moist shining membrane which was evidently an exudate. It did not seem to bleed and could not be stripped off. This seemed to be associated with a fibrosis, as manifest by the firmness of the union of the exudate to the subjacent parts, second by the bloodlessness of the surface, and third because at the posterior nares there was a narrowing by fibrous contraction. It was not the clinical picture of membranous rhinitis or diphtheria, nor of syphilis or of rhino-scleroma. The son thought the eye trouble was caused by the nasal disease. A von Pirquet test gave no reaction. A Noguchi test was also negative. A culture from the secretion of the eyes showed the presence of streptococci and pseudo Klebs-Loeffler bacilli. The treatment consisted of tonics and the local use of atropin, boracic acid, protargol, olive and castor oil, and albolene. No attempt was made at operation as the patient objected.

Fehr exhibited at a meeting of the Berlin Ophthalmic Society in February, 1911, a man of 29, who became infected with lues in January, 1910; at the beginning of March he had sore throat, followed by severe inflammation of both eyes; early in May was admitted to hospital on account of the extremely painful condition of the eyes, along with severe ulceration of the throat and cutaneous syphilides. The eyelids were red, and so much swollen that they could hardly be opened. The conjunctiva was greatly shrunken, so that there was hardly a palpebral aperture at all. One long bleb was visible at the margin of the upper eyelid of the right eye, whose cornea was partly opaque near the margin; the epithelium of the visible portion of the cornea was lifted in the form of a bleb; the other eye was in a similar condition. On the 24th of May he received an injection of 0.8 grams of salvarsan, which had a very beneficial effect upon the general condition, upon the throat and upon the skin. Unfortunately, the effect upon the eye was very short-lived, and in a few months total ankyloblepharon existed in the right eye, and partial adhesion with dense pannus in the left one. Transplantation of mucous membrane from the lip gave a marked but, unfortunately, not a permanent improvement, for again there was much shrinking. An interesting speculation in regard to the case is: Should the syphilitic infection be regarded as the direct cause

of the severe pemphigus of the conjunctiva and the subsequent shrinkage, or as an indirect cause only, by lowering the vitality of the tissues and undermining their resisting power? It should be noted that at least one similar case has been recorded. According to Adam the case is to be regarded as peculiar also, in that the pemphigus outbreak was limited to the eye alone, and did not form a part of a more general eruption.—(C. P. S.)

Conjunctiva, Pigmented patches on the. These are usually found at the limbus. It is not always easy to tell whether they are at present or prospectively malignant. A large number of cases tabulated by Strouse originated in these black or brown patches, and in many cases the growth began to develop after a traumatism. These patches are sometimes congenital and show no tendency to increase in size throughout life. On the other hand they sometimes serve as the focus of a malignant process, particularly when they are not congenital. In the possibly malignant form the patch is black, and not brown as in the congenital variety, and it increases in size by a confluence with other patches or points which spring up in its vicinity.

Extirpation is the only treatment of malignant or supposed malignant growths.

Köllner, before the Berlin Ophthalmological Society in 1909 *(Ophthal. Review,* 1910, page 64), showed a drawing of a woman of 50 with extensive pigmentation of the conjunctiva. About three-quarters of the cornea could be made out with a lens to be invaded by a fine network of minute brown pigment dots lying quite superficially in the epithelium. Microscopic examination of a piece of excised conjunctiva showed that in it also the pigment granules were quite superficial in the epithelium, lying even in the old cells. The pigment sometimes filled the whole cell; it gave no iron-reaction. So far as regards the cornea the case is believed to be unique. Gutmann at the same time mentioned the case of a girl of 20 who presented a somewhat similar patch of pigment on the scleral conjunctiva, which looked exactly like a pigmented nævus, and had recently increased in size. He removed a piece, and as in Köllner's case, there were no nævus-cells, and the pigment was not in masses, but, as in this instance also, in the epithelium; it lay, however, in the deeper layers of it, disposed indeed much as the pigment normally lies in the tissue of the negro.—(C. P. S.)

Conjunctiva, Pinguecula of the. A small yellowish-white tumor of the conjunctiva, situated between the cornea and the canthus of the eye. It occurs most frequently in persons who have been exposed to much dust or high winds. The small, yellowish elevation measures two or three millimeters in diameter, and is movable on the sclera. It consists

of a thickening of the conjunctiva, particularly in an increase of the elastic fibres, and the deposition of numerous minute hyaline particles. If the tumor causes annoyance by its appearance or by becoming inflamed, it may be removed by excision.

A peculiar papular swelling of the bulbar conjunctiva frequently seen in India, which is probably a form of pinguecula, is described by Herbert (*Trans. of Ophthal. Soc. of United Kingdom*, March, 1912). It is rather more prominent than the ordinary pinguecula, ranging up to about 5 mm. in diameter. The color is commonly pale pink, sometimes almost white, with no trace of pingueculous yellow. The surface may, but more commonly does not, stain with fluorescein.—(C. P. S.)

Conjunctiva, Plasmoma of the. Hyalin and amyloid degeneration of the conjunctiva. This term was introduced in 1908 into ophthalmologic literature by Pascheff with a description of three cases (von Graefe's *Arch.*, 67 and 71). Rund published a similar case, which he classed under the group of aleukemic heteroplastic lymphomas. An identical case is reported by Deutschmann (*Zeitschr. f. Augenheilk.*, March, 1912). It was characterized by a chronic thickening of the conjunctiva of the upper lid without symptoms of irritation. The surface was smooth, with a yellowish shine from the interior. The tumor was fixed to the tarsus and extended from one canthus to the other, without involving the retrotarsal fold. Excision was easy; it was detached from the tarsus without difficulty.

Microscopically, it consisted of *plasma cells* (the term introduced by Waldeyer in 1874 for certain cells of the connective tissue whose origin von Marschalkó attributes to the lymphocytes of the blood). These cells showed no dependence of the adventitia of the vessels. There was no hypertrophy of the submucous tissue. Therefore Deutschmann considers it as a true tumor, not an inflammatory irritation. Clinically, the affection could not be distinguished from hyalin and amyloid degenerations of the conjunctiva, which also shows histologically an enormous formation of plasma cells and more or less marked new formation of vessels. The author proposes to designate all these tumors plasmomas, because they are real new formations and all consist of plasma cells.

Two cases reported by Rados (*Zeit. f. Aug.*, Feb. 29, 1913) were characterized by lobular form and smooth surface, and were located in various portions of the conjunctiva, chiefly the retrotarsal folds. Besides plasma cells they contained numerous polynuclear leucocytes and lymphoctyes, which indicated their local inflammatory nature. This was confirmed in both cases, especially in the first, which showed trachoma in the cicatricial stage and pannus. See, also, **Conjunctiva, Amyloid degeneration of the.**

Conjunctiva, Polypus of the. This form of tumor is rather uncommon on the conjunctiva, in fact, is denied by some observers, and when found is usually situated over the caruncle.

There is a marked structural difference between this form of growth, and a granulation, with which it is sometimes confounded. In the latter there is no epithelium or mucous covering, whereas all true polyps are covered by epithelium and have a smooth even surface. Their substance is composed of connective tissue and blood vessels. In size they seldom exceed that of a pea; they are very vascular and bleed easily. They should be treated the same as granulations. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Psoriasis of the. It has been stated that in this disease of the skin the conjunctiva is sometimes affected, but according to Lawford there is insufficient evidence to establish a causal connection between the disorder of the skin and the inflammation of the conjunctiva.

Conjunctiva, Reflection of the. At the line of reflection of the conjunctiva there is more or less subconjunctival areolar tissue, to which the conjunctiva is very loosely connected. The course of the line of reflection extends one or two mm. beyond the outer canthus, but does not pass the inner canthus at all. Beginning at its outer end, just beyond the canthus, it rises and falls rapidly behind the upper and lower lids, respectively. At the distance of 2 mm. inside the outer canthus it is 14 mm. above the outer line of closure of the eyelids and sinks 2 mm. below it; at about the middle of the opening it is 17 mm. above and 4 mm. below; at the beginning of the lachrymal bay it is 9 mm. above and about 3 mm. below.

Conjunctiva, Rhinosporidium Kinealyi of the. R. H. Elliot, and A. C. Ingram (*Ophthalmoscope,* August, 1912), report a case of rhinosporidium Kinealyi of the conjunctiva of five years' standing, in a Mohammedan male, 60 years of age. Examination showed a pendulous semi-circular cutaneous overgrowth, loosely overhanging the upper part of the superior maxillary bone, measuring 20 mm. horizontally in its broadest part, 13 mm. vertically and 9 mm. in thickness. It had a fibrous feel and was not adherent to the deeper structures.

Eversion of the lower lid showed a second mass on the outer two-thirds, of a reddish, irregular, granular appearance, with a number of white patches on it, which appeared to be retained secretion. Large tortuous vessels could be seen over its surface, and upon pinching up the skin-fold from the outside the palpebral mass could be felt projecting between the folds, thick, creamy pus escaping from the follicles.

A third mass was situated close to the inner canthus, elastic and

rounded, giving the appearance of containing tense fluid. The skin was freely movable over it, and it laid in the segment of the orbit, downward and internal to the eye.

The tumors were removed and exhibited the following pathologic structure: (a) An irregular growth of tough consistency covered by skin, save at its base, consisting of fibrous connective tissue with some irregular proliferation, covered by a somewhat flattened layer of stratified epithelium, bearing hairs. There was one large irregular cystic space, full of granular material, with a wall formed of flattened fibro-cellular tissue; also a few small empty spaces which appeared to be dilated lymphatic spaces. The large cyst was larger than rhinosporidial cysts usually are, and had no cuticular wall; it was probably an old blood cyst whose contents had become degenerate. Its origin was probably traumatic and not parasitic. (b) A conjunctival polypus removed from beneath the cutaneous growth (a). It consisted of fibrous and fibro-cellular tissue containing a considerable number of typical cysts of rhinosporidium Kincalyi of all sizes and scattered irregularly through the tissue. The surface of the polypus was covered by an irregular layer of transitional epithelium, and close to the surface were a number of large cyst spaces full of granular material, and lined by an irregular layer of epithelium. Almost all the parasitic cysts were more or less distorted and degenerate. The mass from the inner and lower portion of the orbit resembled the first in structure, somewhat less fibrous and containing a great many well-formed cysts of rhinosporidium Kinealyi. See **Bacteriology of the eye.**

Conjunctiva, Saemisch catarrh of the. See **Conjunctivitis, Vernal.**

Conjunctiva scleræ, Conjunctiva scleroticæ. (L.) Bulbar conjunctiva. The mucous membrane covering the anterior third of the eyeball, from the fold of transmission or retrotarsal fold to the corneal margin. It is loosely connected with the sclerotic, is much thinner than the conjunctiva covering the retrotarsal fold, and loses its papillary structure. The epithelium of the ocular conjunctiva is continuous with the anterior corneal epithelium. See **Conjunctiva, Ocular.**

Conjunctiva, Soft fibromata of the. There is a form of polypoid growth called *papilloma,* or sometimes *soft fibroma,* which differs from a true polypus in being larger and usually with an uneven surface like a wart and having a structure similar to that of a condyloma. It grows by preference from the caruncle, but is found also in the palpebral conjunctiva. The structure is truly papillomatous in typical cases,—a central vessel for each papilla, with some connective tissue

elements, but composed mostly of epithelium, arranged quite regularly in layers, squamous on the surface and columnar in the deeper parts.

An instance of this rare condition is described by Wyler (*Ophthalmic Record*, February, 1911). Upon drawing down the lower lid a pink nodule about the size of a bean, extending from the conjunctiva just below the tarsal cartilage and somewhat to the inner angle was noticed. The mass was soft and firmly attached with a broad base. Manipulation started it bleeding. Wyler thought that he had a cyst to deal with; the location was outside of the Meibomian glands, and it could not be a chalazion.

After getting the tumor in the grasp of a large chalazion clamp and injecting a 1 per cent. solution of cocaine, he carefully circumscribed the mass with a small scalpel, undermining and removing it with scissors. He next closed the conjunctival wound with two silk sutures. Perfect healing followed in three days.

The tumor was placed in normal salt solution and sent to the laboratory for immediate investigation. The sections were cut and stained with hematoxylin and eosin for examination. Inasmuch as the specimen was rather poorly made, the histologic elements were not evident in an absolutely satisfactory manner. The epithelium of the conjunctiva was seen covering the tumor, except at its upper surface, which showed a growth of granulation tissue due to the first incision, before the complete excision was performed. The rest of the section displayed nothing but fibrous connective tissue, with spindle-shaped nuclei and many blood-vessels. The microscopic examination admitted of only one possible conclusion, namely a *fibroma* of unmixed variety. The gross appearance together with the tendency toward bleeding and the soft consistency of the mass made one limit the tumor to one of the soft variety. See, also, **Conjunctiva, Tumors of the.**

Conjunctiva, Sporotrichosis of the. This has been reported by Morax, Cruchandeau, Gifford, Wilder, and others. Thickening of the lid, nodular swelling of the conjunctiva, superficial yellowish ulcers, and adenopathy were present. Syphilis, tuberculosis, and blastomycosis must be excluded by cultivating the germ on maltose agar. The *Sporothrix Beurmanni* is the fungus which usually is the active agent (de Schweinitz).

J. Chaillons reports a case of primary conjunctival sporotrichosis (*Annales d'Oculistique*, January, 1911). The patient was a man aged 28, who was employed in a slaughter-house. It is not without significance that, at the time of onset of the first symptoms, the patient was attending to a horse which had a discharge from both its eyes. The

animal had, however, been killed before the patient was first seen, and the connection, if any, between the discharge from the horse's eyes and the onset of the symptoms in the attendant must remain conjectural. When first seen the patient gave a history of three days' discomfort, itching, discharge, and gumminess of the lids in the morning. These symptoms were confined to the right eye. On examination at this date the preauricular gland, on the same side, was found to be slightly enlarged and tender. The right upper lid was swollen and drooping. Throughout the entire extent of the superior fornix were scattered vegetations varying in shape and size, the smallest being about the size of a pin's head, the largest as big as a bean. Accompanying these vegetations were shallow erosions. These latter were of a whitish-yellow color, and were situated in some places on the vegetations themselves, and in others on the surrounding conjunctiva. The latter was of a reddish-violet color. The superior tarsal conjunctiva was thickened, and covered with small vascular granulations. From the patient's history and the general aspect of the lesions the condition was regarded as possibly tubercular, but negative results were obtained by inoculating guinea pigs with a portion of the diseased tissue. Cultures, however, were grown in twelve days after incubation at the laboratory temperature. The colonies, fifteen in number, were black in color and definitely raised above the surface of the medium.

Examination under a microscope disclosed the presence of a mycelium, which was identified with *sporotrichum Beurmanni.* At a later visit, after nearly a year's interval, the local condition showed no appreciable change, but the preauricular adenitis was more marked, and there was, in addition, an enlargement of the superficial glands of the sterno-mastoid chain on the right side.

Chaillons remarks on the superficial resemblance of the lesions in his case to those in a case of Parinaud's conjunctivitis, and he emphasizes the importance of excluding sporotrichosis in such conditions. See, also, **Sporotrichosis of the eye.**

Conjunctiva, Staining of the. See **Conjunctiva, Argyriasis of the.**

Conjunctiva, Succulent thickening of the. Several cases have been reported of a peculiar reddish-brown succulent thickening of the conjunctiva surrounding the cornea to an extent of from six to eight mm. In most cases the periphery of the cornea is also involved, and in some the process has penetrated the sclera to the interior tissues, followed by loss of the eye. All are not probably of the same origin or pathological character. Rheumatism has been present in some cases, and a suspicion of syphilis in others.

One case, examined histologically by Schlodtmann in 1897,

showed an enormous enlargement of the lymphatics under the epithelium, and the infiltration, in addition to round cells and necrosed tissue, contained many giant cells. See, also, **Conjunctiva, Lymphoma of the.**

Conjunctiva, Syphilis of the. Not only hard and soft chancre, but gumma, papular syphilides, mucous patches and a specific catarrhal conjunctivitis resembling the follicular form of trachoma, are known. The treatment of all these should, of course, be antiluetic, combined with the exhibition of suitable local remedies. The tumors mostly call for operative interference and the employment in those of recurrent tendency of the X-rays or radium.

In a case of hard chancre of the conjunctiva, reported by Aubineau, there was a yellowish-white exudate on the lower lid which in about a week invaded the cul-de-sac, and extensive chemosis soon appeared. The preauricular gland swollen to the size of an almond, was hard and indolent. The submaxillary glands soon became involved. The eyelid was edematous, and induration prevented eversion of the lid. The exudate which at first was of pseudo membranous character, was replaced by a shallow ulcer with irregular outlines, whose whitish color contrasted with the red of the surrounding conjunctiva. At the end of three weeks spirochetes were found in scrapings from the ulcer, and a week later there was well marked syphilitic roseola, and treatment with bichloride was commenced. In five or six weeks the cornea became cloudy, with the appearance of parenchymatous keratitis. At the end of two months the search for spirochetes was negative. At the end of ten months the skin of the lid was flabby, the lashes had disappeared, the palpebral conjunctiva was cicatricial and dermatized. There was an extensive symblepharon, the cornea was cloudy and vision was reduced to counting of fingers, a result that makes it seem likely that an earlier and more vigorous mercurial treatment by inunction or injection might have considerably modified. See, also, **Chancre of the conjunctiva** and **Conjunctiva, Chancre of the.**

Conjunctiva, Syphilitic ulcers of the. The specific sore of syphilis when found on the conjunctiva is usually caused by kissing, and is thus sometimes conveyed from nurses suffering from mucous patches to the eyes of the children under their charge. Infection may also be carried by the fingers which have been handling a sore. These sores have the characteristics of specific ulcers on other parts of the body. The diagnosis is not very difficult where there is well-marked induration, but there are ulcers which are soft and in which the history of infection is more than doubtful. The preauricular and

submaxillary glands are swollen and hard in true chancre. The doubtful cases have the appearance of the so-called rodent ulcer. These, as well as the undoubted syphilitic sores, occur usually on or near the edge of the lid, though they are sometimes found on the bulbar conjunctiva and the retrotarsal fold. True syphilitic ulcers will heal rapidly under the internal administration of mercury with local application of mild antiseptics. No attempt should be made to destroy them with caustics. See, also, **Conjunctiva, Syphilis of the.**

Conjunctiva tarsi. (L.) PALPEBRAL CONJUNCTIVA. Same as **Conjunctiva palpebræ.**

Conjunctiva, Telangiectasis of the. NÆVUS. See **Conjunctiva, Tumors of the.**

Conjunctiva, Temperature of the. It has been found after careful investigation that the temperature of the cul-de-sac of the conjunctiva near the outer or inner canthus is usually from about 0.3 to 0.4 degree C. lower than that of the mouth; and that of the conjunctiva immediately over the cornea it averages 0.1 degree C. lower than at the outer or inner canthus.

By employing the method of measuring the temperature of the conjunctiva recommended by Lucien Howe (*Journal A. M. A.*, Sept. 27, 1913), it is possible to tell to what extent cold or hot applications to the outer surface of the lids really change the temperature of the conjunctiva. Howe found in one case that when pieces of cotton moistened with ice-water were applied to the lids in rapid succession four or five minutes, the temperature of the conjunctiva could easily be reduced 1 or 1.5 degrees centigrade, but that the difficulty in reducing the temperature below that, increased rapidly with each fraction of a degree. Howe emphasizes the importance of the question of temperature in connection with the treatment of bacterial infections. The vitality of many forms of bacteria is lessened in proportion to the decrease in temperature. Practically, however, it is difficult or impossible to produce such a change in temperature as prevents the growth of these bacteria in the test-tube.—(C. P. S.)

Conjunctiva testiculi. (L.) The internal layer of the tunica vaginalis of the testicle.

Conjunctiva, Tortuous and enlarged veins of the. This condition is not uncommon as a result of previous disease, with no other inflammatory symptoms. It may be caused by glaucoma, or from some general vascular change, as in alcoholics.

Occasionally, however, true varix of the conjunctival veins occurs. Three cases were described by Burnett, all of which were found on the

ball near the lower retrotarsal fold, and were not associated with any past or present inflammatory affection of the eye. They appeared as a pyramidal bunch of blue veins with the apex toward the cornea. (See figure.) Pressure from before backward emptied the vessels completely. With this indication he ligated the bunch at the base, with the effect of causing the tumor to disappear permanently. In one of the cases the mass of veins contained two phleboliths one two, and the other six mm. in diameter. The surface of these two bodies was perfectly smooth, and they were as hard as shot. They were decalcified, and on section their laminated structure was beautifully shown.

Varices of the Conjunctiva.

Conjunctiva, Tuberculosis of the. Conjunctivitis tuberculosa. Tubercular conjunctivitis. Primary tuberculosis of the conjunctiva. Tubercle of the conjunctiva. The ulceration in this condition is primarily of the conjunctiva, while in the disease called *lupus conjunctivæ* by the older writers, it begins in the skin and passes over to the conjunctiva. The tubercle bacillus is found in both conditions. The first appearance of the disease is a thickened portion of the conjunctiva with one or more yellowish nodules, some of which may already be in a state of ulceration. The ulcer has ragged edges and its bottom is uneven and " worm-eaten " in appearance, is covered with more or less pus and broken-down tissue, and may have considerable induration around it. Any portion of the conjunctiva of the ball or lids or retrotarsal folds may be affected. The nodules vary in size from that of a pin-head to a destruction of tissue embracing almost the entire surface of the conjunctiva. When the conjunctiva next to the cornea is affected, the cornea itself, even when not involved in the

ulceration, becomes more or less opaque. When the disease is exterior and involves the opposing surfaces of the conjunctiva of the ball and lid, an adhesion between the lid and the ball (symblepharon) takes place during the process of cicatrization. In some instances this has become total. The lids are usually thickened considerably, but are not hard, and there is commonly a rather scanty discharge of muco-pus. The granular-looking ulcers bleed only on rough handling. There is not much pain except when the cornea is involved. The disease may be limited to one eye, but both are often affected, either simultaneously or in succession. The preauricular and submaxillary glands are enlarged on the affected side.

Tuberculosis of the conjunctiva may be a primary affection and occur in persons in whom there is no evidence of its existence elsewhere. In such cases it is due to direct infection, through an abrasion of the epithelium by a foreign body, or through an operation, or through the breaking of a phlyctenule. This last seems the more probable, since the disease is found mostly in children, in whom phlyctenulæ are common. The ulceration in rare cases passes over the edge of the lid to the integument, but usually stops short at the inner edge.

The disease is essentially chronic in its course and in most cases it remains a purely local affection.

It might be supposed that the diagnosis of tuberculosis would be easy by a simple bateriological examination. It is true that in most cases there is no difficulty in demonstrating the existence of the tubercule bacillus either by direct microscopic examination, or by an inoculation of animals, but there seem to be exceptions. Bacteriology has not yet become so exact that we can rely upon it solely and absolutely in diagnosis. In a case reported by Burnett, which was under his observation for more than a year, there was an extensive destruction of the conjunctiva in both eyes, one of which was practically lost, and the case presented a typical clinical picture of the disease, yet he was never able to find a single bacillus after numerous examinations, and inoculations of rabbits gave negative results. In another instance, however, the inoculation experiment proved the diagnosis after repeated trials had failed. Undoubtedly many mild cases of infection pass by unnoticed or are mistaken for more than ordinarily obstinate phlyctenulæ.

When the nodule or ulcer is small its extirpation by the knife or destruction by escharotics is indicated as the quickest and safest method of dealing with it. Of the escharotics, the actual cautery, and galvano-cautery, are the more radical, while nitrate of silver, pure carbolic acid, and formalin, pure or 1 to 10 or 20, are less severe, can

be repeated more frequently, and are more easily modified in their effects. Milder antiseptics and aseptic solutions may be used for cleansing purposes when the surface affected is too extensive to permit of the stronger measures. Formalin, 1 to 1,000 or 1 to 2,000; bichloride, 1 to 5,000; saturated solution of boric acid, or dusting with iodoform powder. The general treatment and hygienic management suitable to the tuberculous diathesis are indicated and should be carried out.

The opening of the lids leaves the conjunctiva in direct contact with the external air and a great variety of germs are deposited upon its surface. Though the bacillus of Koch has not been met with on the normal conjunctiva, there is no doubt that it is often deposited there with the dust of the air that carries it. The conjunctiva may be compared in this respect to the other cavities of the face, the buccal cavity with the pharynx and tonsils and the nasal fossa with the accessory sinuses, and tubercular bacilli have often been found in them.

Cabannes (*Archives d'Ophtal.*, January, 1906) calls attention to the distinctness with which the infection, fortunately remaining local, was propagated in the neighborhood step by step. Tuberculosis of the skin of the face, of the preauricular glands and then of the maxillary and cervical glands. He has studied a number of published cases with reference to the organs secondarily affected and considers the usual order of infection to be cornea, sclerotic and ocular globe; lachrymal passages, distant organs, generalization. Corneal lesions, rare in conjunctival tuberculosis, often so closely resemble those met with in trachoma that they can be distinguished only by microscopic and bacteriologic examination. Propagation by the sclerotic is exceptional. The destruction of tissue may not pass the selcrotic, but in some cases has penetrated it and set up panophthalmitis. Extension of tuberculosis from the conjunctiva to the lachrymal sac is rare, and even doubtful, while extension from the nose is comparatively common.

The first important stage in the propagation of tuberculosis from the conjunctiva is the glandular stage. The first glands affected are the preauricular and parotid, corresponding to the lymphatics of the outer two-thirds of the conjunctiva, and the submaxillary glands which are connected with the lymphatics of the internal angle of the eye. The order of frequency of involvement is: the preauricular, the submaxillary, the cervical, the parotid and the masseteric.

The glandular enlargements may be so extensive in the beginning as to mask the conjunctival affection, which is not detected until later. The glands sometimes suppurate.

Sometimes the infection proceeding from the conjunctiva to the glands stops in its course to produce a tuberculosis of the cheek.

When the tubercle bacillus reaches a gland it develops there, and even if it is exceptional to find it in the secretion, inoculation in animals gives positive results.

Most frequently tuberculosis of the conjunctiva does not pass the barrier of the glands. It may, nevertheless, in exceptional cases, by way of the lymph or blood, reach more distant organs and end in death by pulmonary or laryngeal phthisis, generalized tuberculosis or tubercular meningitis, and should, therefore, be diagnosed early and energetically treated. Repeated thermocauterization is recommended in the treatment of this affection.

Eyre, in a Hunterian lecture (*Lancet,* May 18, 1912), gave a comprehensive review of the etiology, pathology, and diagnosis of tuberculosis of the conjunctiva.

The lecture opened with an historical survey of the subject, and this included statistics on the probable case incidence of the disease. These latter varied from Hirschberg's figures of 1 in 17,000 to Stephenson's of 1 in 1,500. As a result of his previous statistics and also of more recent ones obtained from the out-patient department of Guy's Hospital Eyre was inclined to think that his former figures of 1 in 2,700 are approximately correct.

The diagnosis naturally falls under two heads, clinical and laboratory methods.

Clinical methods. (1) The type of the disease.

For the purposes of this lecture the author analyzed a series of cases in which the diagnosis had been rendered certain by the recognition of the tubercle bacillus or by an inoculation experiment, and divided them into five groups:—

(1) Ulceration	46	cases
(2) Miliary tubercle	25	"
(3) Hypertrophic granulation	80	"
(4) Lupus	46	"
(5) Pedunculated tumor	9	"

The author doubts the comparative frequency of lupus, as he considers that while the other forms are not infrequently overlooked, lupus, being generally associated with the same complaint on the face, is always recognized. He believes that all cases would really belong to group 2, *i. e.,* miliary tubercle, if they were seen at a sufficiently early stage, the subsequent differentiation into the other forms being, in all probability, due to variations in number and virulence of bacilli and various cell susceptibilities in different individuals. Thus groups one

and three indicate the inoculation of susceptible individuals with large numbers of virulent bacilli, the reverse being the case in group five.

The rest of the clinical portion deals with the clinical demonstration of hypersensibility toward the toxins of the tubercle bacillus. Under this heading the author deals with (1) Cutaneous reaction (von Pirquet); (2) The dermal reaction; (3) The intradermal reaction (Mantoux); (4) Subcutaneous test (Koch); (5) Ophthalmo-test (Calmette). These he describes carefully and comes to the conclusion that none of them is really suitable for the present purpose. The only other clinical point of value in this connection is the result of treatment. If we assume that an individual presenting definite lesions is infected with B. tuberculosis, and treatment specifically directed toward the production of immunity to the tubercle bacillus results in the disappearance of the lesion and the return of the individual to normal health, there is strong presumptive evidence that the lesion was due to infection with B. tuberculosis.

(1) *The microscopical and bacteriological examination of the local lesion with a view to the detection of bacillus tuberculosis.* For this purpose Eyre recommends that the tissue removed, which in group one may consist only of scrapings, should be divided into three portions after being received into a sterilized glass capsule containing a small quantity of normal saline solution warmed to 37° Cent. The first portion should be made into an emulsion in a sterilized glass or agate mortar from which films are prepared and stained by Ziehl-Neelsen's method. Should these not show any tubercle bacilli some of the emulsion should be added to a few cubic centimetres of antiformin (equal parts of 16 per cent. NaOH and Eau de Javelle), and placed in the incubator at 37° C. At the end of this time the tissue will be found to be completely disintegrated, and the turbid fluid may now be centrifugalized and the deposit used to make film preparations on albumenized slides. Frequently this plan will enable tubercle bacilli to be found where previously they were regarded as absent, and owing to the fact that antiformin used in this way destroys practically all bacteria except B. tuberculosis, this plan should be adopted if it is intended to attempt to cultivate the organism directly from the tissue—in which case the remainder of the deposit should be planted on to Dorset's egg medium in tubes.

The second part of the tissue should be hardened and sectioned in paraffin. Any of the ordinary fixing agents with the exception of Müller may be used, and the author expresses a preference for aniline hydrochloride as a decolorizing agent. The author here gives a detailed account of the microscopical appearances that are found in

the various groups. The third portion of tissue should be used for experimental inoculation.

(2) *The biochemical examination of the patient's blood serum with a view to the detection of specific antibodies.* The specific antibodies which are generally the objects of search in these investigations are (1) agglutinins; (2) in general such specific antibodies as are capable of fixing complement; (3) opsonins. With the two first the author does not deal in detail as he does not consider their reactions sufficiently accurate or consistent to be of value in diagnosis.

In dealing with opsonic indices the author lays stress on the necessity for serial samples, a chance sample being of little or no value. Under ordinary conditions even a series of samples only indicates that the patient suffers from a tuberculous lesion but does not afford any indication as to its site. If we now provoke an auto-inoculation by massaging or otherwise stimulating the local conjunctival lesion the opsonic curve will now afford the necessary information.

As to general points such as medical and family history, etc., Eyre has nothing fresh to add. As regards the type of bacillus, whether human or bovine, he expresses the opinion that about 72 per cent. of cases of tuberculosis of the conjunctiva are due to the former. The path of infection he regards as practically always exogenous, but does not deny the possibility of the rare occurrence of infection from the blood stream.

In addition to surgical removal of all diseased tissue, as far as that may be done without excessive scarring, Eyre is strongly in favor of the use of Koch's tuberculin T.R. and insists on the necessity for prolonged treatment. He instances 11 cases under his care, in only one of which was this treatment unsuccessful, and in this case there was extensive nasal infection as well. The initial dose used has been as small as 1/20,000 mgr. and the maximum has never reached 1/2000 mgr. The interval between the doses varied between seven days and three weeks.

F. Re (*Archivio di Ottalmologia,* 1913, p. 515) describes four cases. In each one there was a typical ulceration of the tarsal conjunctiva, with raised edges, and surrounding papillary enlargement. In three cases histological study and animal inoculation confirmed the diagnosis. All four were successfully treated with a four per cent. salve of picric acid in vaselin and lanolin. Twice (or sometimes three times) daily the ulcerated surface was spread thickly with the salve, cocain having previously been instilled. The immediate result was disappearance of the discharge which had covered the ulcer. The ulcer was gradually filled with granulation tissue, until after two or three months its site

was occupied by a nodule covered with marked papillary hypertrophy. One case only was seen after the lapse of a year, when the diseased area was represented by a small scar.

A. Gasali (*Annali di Ottalmologia,* 1913, xl, p. 492) reported the case of a child of four years, with slight physical signs of tuberculosis at one apex, and a history of trouble beginning in the right eye four weeks earlier. The tarsal and transitional conjunctiva showed papillary hypertrophy, and numerous grayish-yellow nodules, some of which were eroded. Excised tissue revealed a tubercular structure and some Koch bacilli, and animal inoculation produced tuberculous iritis. Fourteen twenty-minute applications of radium, seven on each half of the lid, were made between March 22nd and July 11th. By May 15th the papillary hypertrophy had almost completely disappeared, and the nodules were less numerous and less prominent. On July 25th the only evidence left of the disease was a pale cicatricial aspect of the conjunctiva of the cul-de-sac. Brief reference is also made to five other cases in which treatment with radium resulted in cure. They include three cases of lupus of the conjunctiva, and two of conjunctival tuberculosis. In cases of conjunctival tuberculosis not suited for the combined use of surgical removal and cauterization, radium therapy is indicated, and is superior to the Roentgen ray.

J. J. Thompson (*Annals of Ophthal.,* January, 1906) reports the case of a female, æt. 24, who exhibited a primary tuberculosis of the conjunctiva. She applied for treatment because of swelling of the preauricular gland and a peculiar feeling in the right eye of a few weeks' duration. There was found, upon everting the upper lid, an ulcer of 2 mm. in diameter situated at about the center of the tarsal conjunctiva. Its edges were clear cut and its base was clean, very slight induration surrounding it. Later a very small ulcer made its appearance 1 mm. from the original one. No family or personal history of tuberculosis could be obtained. Physical examination was negative. Scrapings from the ulcer failed to show tubercle bacilli. An injection was made into the peritoneum of a guinea-pig. This animal finally died of general tuberculosis. The preauricular gland continued to enlarge and was enucleated. Examination of it showed several typical anatomical tubercles, with a fair number of giant cells. The ulcer was now attacked by removing it with the surrounding tissue. The usual regimen for tubercular patients ordered. The ulcer healed in two weeks. No recurrence of the ulcer or glandular swelling. The author believes that the lid ulcer was due to local infection and not to any deposit carried by the blood stream.—(C. P. S.)

Conjunctiva, Tumors of the. Both benign and malignant growths occur

in the conjunctiva. Of the benign growths the so-called *granulation tumor* is the most common. It accompanies the healing of wounds, and injuries of the conjunctiva, and is very common after the operation for strabismus. Foreign bodies imbedded in the conjunctival substance, particularly in the cul-de-sac, cause these granulations to spring up around them, and the bleeding from their surfaces gives rise to the phenomenon of *bloody tears*. It is found on the inside of eyelids at the seat of a chalazion when it has broken through its inner wall and discharged into the conjunctival sac.

Granulomata are soft in the beginning at least, irregular on the surface, and have broad bases. They gradually become pedunculated and smoother on the surface, and sometimes, when the pedicle gets very slender, are rubbed off by the action of the eyelids. When situated on the inner surface of the lids they are flattened by the pressure of the lids on the ball. They should be treated by removal by the scissors or by torsion when the pedicle is sufficiently slender. When the base is broad, cauterization of the stump after removal is advisable in most cases.

Polypus of the conjunctiva is sometimes confounded with granulation, but there is a marked difference between them. In granulation there is no epithelium or mucous covering, while all true polyps are covered by epithelium and have a smooth, even surface. Their substance is composed of connective tissue and blood vessels. This form of tumor is uncommon on the conjunctiva, in fact is denied by some observers, and when found is usually situated over the caruncle. They are small, seldom exceeding the size of a pea. They are very vascular and bleed easily. They require the same treatment as granulations.

Papilloma or as it is sometimes called *soft fibroma*, a form of polypoid growth, differs from a polypus in being larger and usually with an uneven, wart-like surface and having a structure similar to a condyloma. It is usually found on the caruncle, but sometimes is seen in the palpebral conjunctiva. In typical cases the structure is truly papillomatous—a central vessel for each papilla, with some connective-tissue elements, but mostly composed of epithelium, arranged quite regularly in layers, squamous on the surface and columnar in the deeper parts. (See, also, **Conjunctiva, Soft fibromata of the.**)

Dermoid tumors of the conjunctiva are always congenital and nearly always associated with some other malformation or defective development of the eye, particularly coloboma of the lids or of other parts of the face, as hare-lip. They are most frequently found at the sclero-corneal junction, and in such cases the conjunction of the cornea is

involved in the growth. They were first described by Ryba in 1853, who gave them the name by which they have since been known. They contain all the elements of the skin, including hair follicles, sweat-glands, and sebaceous glands. They are hard or soft according to the amount of fatty matter they contain. On the surface, which is like that of integument, there is nearly always hair, usually fine, but occasionally quite large and long. They sometimes increase in size after birth. The lower edge of the cornea is their seat by preference, and they vary in size from that of a small pea to more than double this size. The entire cornea has been covered by one of these tumors. They demand removal principally for cosmetic reasons and on account of the inconvenience they cause. There is a tendency to reproduction if the tissue is not thoroughly excised.

Lipoma of the conjunctiva is a growth composed of fatty matter with a small quantity of connective tissue. It is found under the conjunctiva usually towards the outer canthus, between the superior and inferior recti muscles. There may be, rarely, more than one tumor. They are always congenital and frequently show a tendency to increase in size at about the age of puberty. The surface next the ball is sometimes slightly concave. The average size is about one centimetre in length and one-half a centimetre at the base. They are movable on the globe, and the conjunctiva over them is unchanged or at times slightly thickened. Lipomata have been described which, besides fatty matter, contained some elements of the skin. These have been called *dermo-lipomata.*

Removal of these growths can be easily accomplished when desired.

Bishop Harmon (*Trans. Ophth. Soc. of the United King.*, 1906, page 35) describes a case of symmetrical hairy dermoid of the conjunctiva, involving both the palpebral and ocular portions of the membrane.

Abscess of the conjunctiva occasionally occurs independent of trauma or other morbid process. It is most liable to be found in the caruncle, though it has been found in the conjunctiva of the ball to the outer side of the cornea. Hot applications and an early opening are indicated.

Cysts of the conjunctiva, of the simple serous variety, are uncommon. They may be of traumatic origin, or congenital, and when situated at the corneo-scleral junction they might be placed in the category of dermoids. They contain a clear liquid, sometimes having suspended in it nucleated cells, resembling epithelium.

Another variety is due to the enlargement of the acino-tubular glands of Krause. These are situated near the retrotarsal fold and on the caruncle, where these glands are most abundant. These, and

those due to trauma are beneath rather than in the conjunctival substance, and are not movable on the ball to the same extent as those in the conjunctiva itself. Another variety has its origin in the enlargements of the lymph-channels of the conjunctiva, an exaggerated form of lymphectasia. Under this head will fall those cases which have been reported as due to stings of insects. In these cases, as well as in those of enlarged tubular acinous glands, there is a distinct lining of the cyst-wall with cells.

False cysts are simply circumscribed elevations of the conjunctiva by the aqueous humor that has oozed from a fistula at the sclero-corneal junction.

The sole treatment of cysts is ablation. Recurrences are uncommon.

Osteoma of the conjunctiva is a very rare occurrence (Critchett, Snell). Their usual seat is on the ball near the external commissure. They are usually seen in children and probably are congenital.

Cysticercus. The cysticercus cellulosæ occasionally finds its home under the conjunctiva. If seen at the beginning it shows itself as a transparent cyst in the interior of which the head of the animal may sometimes be seen. There is more or less vascularization of the overlying conjunctiva, which becomes thickened and opaque in time, and then the diagnosis is difficult. The usual seat is on the ball and to the nasal or temporal side of the cornea. More rarely it is found on the retrotarsal fold or the palpebral conjunctiva. It is easily removed through an incision in the conjunctiva.

Another form of entozoon which is occasionally met with in the conjunctiva in hot countries is the *filaria medinensis.* It sets up a severe irritation, ending usually in the formation of an abscess. It is from twenty-five to thirty millimetres in length, and enters the conjunctiva from the orbit. Evacuation of the abscess carries the worm out with its contents. (See, also, **Conjunctiva, Cysticercus of the.**)

Angioma and telangiectasis of the conjunctiva. A nævus of the lid is sometimes carried over and affects the conjunctiva. A true angioma of the conjunctiva alone more rarely occurs. They are usually found on the caruncle and appear as soft red tumors with rather sharply defined limits. They are congenital; and sometimes show a tendency to increase rapidly in size.

Tumors in which the vascular tissue was predominant have been reported (Rampoldi, Kraschinsky, Stefanini) as springing from other portions of the conjunctiva. In one case, however, reported by Bossalino and Hallauer (1895), the tumor was found on examination to be

a pure muscular angioma of the subconjunctival tissue. Prompt treatment is indicated, by the galvano-cautery or excision.

A case is reported to have been cured by Blessig by several injections of perchlorid of iron. Gifford reports the apparent cure of a very large angioma in a four-year-old girl by injections of absolute alcohol. The tumor extended from the caruncle to 3/16 of an inch beyond the centre of the corneal margin both above and below, reaching out into the fornices, but not invading the palpebral conjunctiva nor the skin. The tumor was about ¼ inch thick, overlapping the inner margin of the cornea slightly and flattening out gradually toward the border at the outer side of the cornea. The conjunctiva on the surface was smooth and normal. There had been no pain or inconvenience. From the extent of the tumor, extirpation could not be attempted. The injection of hot water was considered, but it was feared this procedure might possibly result in considerable tissue necrosis, as frequently happens. The injection of two or three drops of absolute alcohol into several parts of the tumor was therefore resorted to. The injected portions at once assumed a pale, grayish-pink color, and in ten days the tumor was much reduced in size. The injections were then repeated, the needle being carried part of the time ½ inch into the orbit along the inner side of the globe. After this alcohol was injected every two or three weeks for the next two months, at the end of which time the original tumor had practically disappeared. After about four months there was no tumor visible and the only trace of the former trouble was a moderate congestion of the inner half of the conjunctiva, which was steadily improving. The injections were always made during light chloroform anesthesia and were followed by only moderate swelling and very little pain; at no time was there any sign of breaking down or necrosis.

Burnett reported a case of genuine hematoma of the conjunctiva, which increased gradually until it had attained nearly the size of a pigeon's egg. As there was some probability of malignancy in the growth the eye was enucleated, but on examination the tumor was found to be a cyst filled with blood which came from the vitreous chamber.

L'Ancona (*La Clinica Oculistica,* January, 1908) reports the case of a child, 2 years old, who had a small, red body behind the lid partly covering the right cornea and visible when the eyes were opened. Pain was apparently not present; there had been no hemorrhage. A more careful examination showed the presence of a small swelling between the lid and cornea. On raising the lid one could see a tumor as large as a big blackberry, of a red-wine color, smooth surface, soft,

elastic consistence, non-reducible by pressure, sessile, implanted by a 2 or 3 mm. base from the tarsal conjunctiva to the superior fornix. The left eye at superficial glance appeared normal, but on raising the lid the same character of tumor, smaller, was seen at the same place with surface slightly uneven. Both tumors were removed with a bistoury after tying off the bases. Hemorrhage was controlled by pressure. Under the microscope sections showed blood vessels dilated and some new formed, others joined to form large cavities. Between the vessels were trabeculæ of connective tissue. The diagnosis was cavernous angiomata of the conjunctiva.

Tortuous and enlarged veins on the conjunctiva, with no other inflammatory symptoms, are not uncommon as a result of previous disease. True *varix,* however, is occasionally seen involving the conjunctival veins.

Lang exhibited a pathological section at the Royal London Ophthalmic Hospital, on April 27, 1905, which showed four large dilated veins, with some smaller channels of the same type, lying close under the conjunctival epithelium, and separated from each other by a fine layer of fibrous tissue. The epithelium varied in thickness, being thinner over that part where the vessels come nearest to the surface. There were no proper vessel walls, but the spaces were lined by flattened endothelium.

Lymphectasia of the conjunctiva resembles small transparent beads, from an obstruction in the lymph channels. It usually occurs in the palpebral fissure between the cornea and one of the canthi. Hirschberg reported a case in which the beads made circles around the cornea. Leber reported a case in a woman in which the lymph was mixed periodically with the coloring matter of the blood,—*lymphectasia menorrhagica.* They are sometimes congenital and as a rule give rise to no trouble. Each globule can be pricked with a needle or the whole mass extirpated.

Malignant tumors of the conjunctiva occur as from other mucous surfaces. Epitheliomata are by far the most numerous of this class of growths. Panas and some others maintain that the so-called sarcomatous forms are really epitheliomata of more rapid growth. Strouse, however, reports cases of true sarcoma of the limbus. Most if not all of these started in the conjunctiva and where the cornea was invaded it was only in the epithelial layers of the substantia propria contiguous. The variety of melanotic tumors which have been described owe their pigment, according to Panas, to their situation near the uveal tract or to hemorrhage and on that account should not be considered as true sarcomata. Some cases of true carcinoma have been described as occurring on the conjunctiva.

A case of an apparently true melanotic sarcoma of the conjunctiva, with pigmented non-sarcomatous growths of the skin, was reported by Roper (*Trans. Ophth. Soc. of the United King.*, 1912, page 117). Except when they pass over from the integument of the lid to the conjunctiva, they are most commonly found at the sclero-corneal margin. This situation, as Fuchs pointed out, is the analogue of the predilection of epitheliomata for the boundary between two kinds of epithelium. These tumors usually grow slowly, but they may in time attain a large size: they grow by preference in the direction of the cornea, sometimes entirely covering it. They may also extend by ulceration into the interior of the eye at the edge of the cornea. The sclera, on account of its toughness, resists the attack of the growth much longer than the other tissues of the eye. Persons in advanced life are almost exclusively affected, and like epithelial growths of the face, remain localized and show but little tendency to metastasis.

The diagnosis is not usually difficult, particularly after ulceration has begun, though it is not always easy to tell whether the pigmented patches sometimes seen at the limbus may not assume malignancy. In the possibly malignant form the patch is black, and not brown as in the congenital variety.

Early extirpation is the only treatment, and if necessary the entire eye should be enucleated.—(C. P. S.)

Conjunctiva, Urticaria of the. Disturbances of the nerve centres, resulting from some toxic agent will sometimes bring on suddenly a chemosis of the conjunctiva in apparently strong and healthy persons. The administration of a single grain of quinine has been known to produce a marked chemosis, following an urticaria from this drug, showing its influence on the vaso-motor system at the periphery. Burning and itching of the conjunctiva, with hyperemia, have been noticed, with the same condition of the face, in attacks which were probably urticaria and caused by the ingestion of food which had before produced a general urticaria. See, also, **Conjunctiva, Chemosis of the.**

Conjunctiva, Vascularization of the. On account of the vascular connections with the structures on the anterior part of the eyeball—the cornea, iris, and ciliary body, the conjunctiva is always implicated with inflammations of these structures. It seldom takes part in inflammatory affections of the deeper structures: the choroid and retina.

The change in its vascularization is the most noticeable feature in an inflammation of the conjunctiva. In health its transparency is but little interfered with by the number or size of its vessels, and the

white sclera is clearly seen through it. In hyperemia or congestion this is greatly altered. The vessels are greatly multiplied in number, the veins are more tortuous and increased in diameter, and if there be any considerable amount of exudation the sclera is obscured or entirely shut out from view, the white of the eye assuming a "blood-shot" appearance. A characteristic feature of this conjunctival congestion is movableness of the vessels over the globe; it is in this way, among others, to be distinguished from that deeper ciliary injection, the so-called "circumcorneal injection," confined mostly to the base of the cornea, which accompanies inflammations of the interior of the eye, particularly iritis and cyclitis, and it is often a valuable point in differential diagnosis. See, also, **Anatomy of the human eye.**

Conjunctiva, Vessels of, during death. The color and the appearance of the vessels on and under the conjunctiva are readily observed objective signs, in this connection. Exsanguinated vessels can be easily distinguished from full ones, and the color of living tissues is readily differentiated from cadaveric lividity. These signs of death are markedly influenced by the character of the death and the degree of the surrounding temperature. In winter, in an emaciated subject, dead of disease for a moderate length of time, the pallor of the conjunctiva is characteristic. In warm weather in a person dying suddenly, there is often present a lividity of the same tissues, accompanied by slight edema. Certain hemorrhagic phenomena are usually more the signs of the mode of death than they are of death itself.

Conjunctiva, Xerosis of the. ATROPHY OF THE CONJUNCTIVA. CONJUNCTIVA ARIDA. XEROPHTHALMIA. The true form of this affection, not associated with any antecedent inflammatory disease, is characterized by great dryness and dullness of the membrane, in which the cornea sometimes takes part even at the beginning. There is a deposit on the surface of the conjunctiva corresponding to the palpebral opening, which resembles fine froth. It is usually in the form of a triangle with its base towards the cornea. This froth if removed, which can easily be done, readily forms again. There is an accumulation of a thick, white, cheese-like material on the edges of the lid. The conjunctiva is more or less anesthetic, and irritation of it does not bring about a flow of tears. In pronounced cases indeed, the lachrymal secretion is stopped entirely. In severe cases the mucous membrane becomes so shrunken as to obliterate the retro-tarsal folds, and assumes almost the appearance of skin. The corneal surface in such cases is very dull, opaque, and almost sloughs. A marked subjective symptom which is rarely absent in those old enough to observe it is night-blindness. In

a subdued light the patients are practically blind. In nearly all cases of idiopathic night-blindness this frothy material is found on the conjunctiva. This night-blindness may occur in children, and in the cases mentioned by Swan Burnett, mostly in young negroes, who seem to be fairly well nourished. It is usually temporary. This milder form has been designated *epithelial xerosis.* It is associated, however, with sclerotic changes in the conjunctiva proper, in addition to the degeneration of the epithelium, according to Basso.

The disease is essentially one of malnutrition, and the most pronounced cases are met with in marasmic infants, although cases have been seen in quite robust persons. It has been observed with great frequency on the coffee plantations in Brazil (Gama Lobo), where it seems, as elsewhere, to be sometimes epidemic, and among negro children in South Carolina (Kolloch). The frothy material on the conjunctival surface was found by Basso in 1897 to consist largely of degenerated conjunctival epithelium and cells coming from the Meibomian glands, and the emulsion-like substance on the edges of the lids has a similar composition. In this material (which is present also at times in the cul-de-sac) there have been found a number of microbes, and some have thought there is a specific form which is a producer of the disease; the microbe most commonly found has somewhat the shape of the Klebs-Loeffler bacillus, the so-called pseudo-diphtheria bacillus, and is frequently present in large numbers. It seems more reasonable to suppose that these microbes come from the outside, the eyes being partially open most of the time, and find in this degenerated material a suitable ground for their development, and that they are in no way connected with the disease. The whole clinical history of the disease shows it to be one of defective nutrition and lowered vitality. That the central nervous system bears the brunt of the burden, the insensitiveness of the retina, as manifested by night-blindness, is strong evidence, though some place the seat of the visual trouble in the cell-layer of the retina. The atrophies of the conjunctiva, the lachrymal gland, and the cornea, would appear to be the peripheral manifestation of the disease. In infants there is most commonly a fatal issue through intestinal or lung trouble.

Associated with some forms of chronic conjunctivitis and keratitis there is found a localized xerosis of the conjunctiva without night-blindness (*secondary xerosis* [Leber]), which probably is the same as the *plaques épithéiales de la cornée* of Hocquard.

Treatment should be directed to improving the nutrition. Locally, asepsis and emollients such as white vaseline are indicated.

Stephenson (*The Ophthalmoscope,* January, 1912) mentions the fre-

quent association of night-blindness with xerosis. The disease, he says, is not uncommon in the neighborhood of London, among the lower strata of society, particularly among the children of the poor-law schools and orphanages. It was found present in 1.87 per cent. of 6209 presumably healthy children. It prevails in summer and autumn, and is seldom seen in the winter months.

The symptoms of night-blindness are often difficult to elicit in children; however, frequently there is a history of stumbling about in the twilight.

The relationship between conjunctival changes on the one hand and night-blindness on the other is not invariable. The one symptom may occur without the other, and vice versa.

Changes in the visual fields were found to exist. These were of two kinds, viz., constant and inconstant. The former consisted in a reduction for the red and green fields. But that was not all, for the field for red was more shrunken than that for green, so that the former lay inside the latter; whereas, under normal conditions, the reverse should, of course, be the case. In three-fourths of the patients examined with reference to this point the transposition was complete, but in the other the two fields overlapped at one or more places. The second or inconstant change lay in a slight contraction of the limits of the field for white.

The so-called "light minimum," as estimated by Förster's photometer, was diminished in both conditions named. The obvious conclusion is that there exists a state of torpor retinæ, but the condition of potential night-blindness is often not discovered on casual examination.

Both in simple xerosis and in xerosis complicated with night-blindness the fundus presented slight departures from normal. Thus, the retinal reflexes were exaggerated, so that the fundus looked paler than usual; while in addition a semi-circular, jagged reflex was often to be observed close to the inner side of the optic disc. These points, although under any circumstances somewhat intangible, were easier to appreciate when ophthalmoscopic examination was conducted under weak illumination with an undilated pupil.

To many of the cases the term "strumous" might fitly be applied. Such appearances as otorrhea, large tonsils, opacities of the cornea, eruptions about the face and ears, swollen upper lips, nasal catarrh, enlarged cervical glands, and synovitis of the larger joints were common among them.

Besides this, it was found that the children with xerosis conjunctivæ, with or without night-blindness, showed a deficiency in the

hemoglobin content of the blood. With Gower's hemoglobinometer, the children affected showed an average of 65 per cent., while examination of the blood of 164 healthy children showed an average of 76.62 per cent. hemoglobin, showing a condition akin to chlorosis, as determined by the blood to exist in these cases.

It is significant that xerosis and night-blindness should occur only in poor-class children, and should make their appearance exclusively in spring, summer and autumn. The dazzling of sunlight appears to be the immediate cause, and it is doubtless intensified by the paving of flagstones, which reflect an uncommon light in the eyes, and the reflection of the whitewashed walls.

Since the white patches are to be found only on that part of the conjunctiva which is exposed to light when the eyes are open, this suggests that under the influence of light, or of some of its elements, the metabolism of the exposed parts undergoes an alteration, and thus allows the xerosis bacillus, an almost constant inhabitant of the conjunctival sac, to lodge upon the parts and to multiply to an enormous extent. Particles of keratin and of keratohyalin are found pathologically in the altered epithelium, and this leads, as Stephen Mayou has pointed out, to an alteration in the surface tension of the affected areas, in consequence of which the oily secretion of the Meibomian glands collects upon them in the form of a white foam. The bacilli themselves play no part in the causation of the symptom complex.

Lastly, the remote cause is to be sought in some slight defect in nutrition, as indicated by the color index of the blood.—(C. P. S.)

Conjunctivitides. The various forms of conjunctivitis. With the exception of those forms of conjunctivitis due to chemical and mechanical causes, all other forms are undoubtedly due to bacteria, although we are not yet justified in founding a classification of the conjunctivitides solely upon bacteriologic causes. The usual method of classification is from their clinical pictures, speaking of the concomitant bacilli and cocci as etiologic factors. See **Conjunctivitis.**

Conjunctivitis. CONJUNCTIVITIS IN GENERAL; CONJUNCTIVAL INFECTIONS. As an introduction to the study of diseases of that most important ocular tissue, the conjunctiva, there is nothing better than the short article by Vossius in the *Encyklopädie der Augenheilkunde*, a portion of which is here quoted. This classification will, as a rule, be followed in describing the various forms of infection and inflammation of the conjunctiva.

Diseases of the conjunctiva constitute 30 per cent. of all the diseases of the eye, according to Cohn; 47.7 per cent. according to O. Becker. The difference in this estimate is partly explained by the fact that the

latter included affections of the cornea which arise from disease of the conjunctiva. As is well known, diseases of the conjunctiva occur with affections, both primary and secondary, of the cornea, so that often there are transition forms between two clinical pictures, as well as complications of one disease by another.

In spite of the recognized advance in bacteriological science, it is not yet possible to classify the cases from a purely etiological standpoint, although in consequence of a broad investigation of etiology the independence of some clinical diseases has been disproved. This is especially true of conjunctivitis follicularis, whose principal sign, an enlarged follicle, is really a symptom of not one but of many diseases of the conjunctiva. Again, conjunctivitis crouposa, a form, once thought to be a clinical entity, is now known to be common to several affections, which are not all even of infectious origin.

Furthermore, we are beginning to recognize combinations of diverse diseases, which in part are mixed infections. For example, the diplobacilli may settle on a conjunctiva that has undergone granular degeneration, or an infection with diphtheria bacilli may become very dangerous through the presence of virulent streptococci, or a phlyctenular conjunctivitis may combine with a purulent catarrh of infectious and even of non-infectious origin. Also it needs to be especially noted that diseases of the skin, especially the lid, may set up secondary ailments of the conjunctiva, which are not always of infectious origin, as evidenced by the various forms of eczema, herpes, acne, pemphigus, and molluscum contagiosum.

In other words, we shall have to fall back on the old clinical classifications, though the etiological relations will assist in clearing up some difficulties. That classification is as follows:

I. Catarrhal conjunctivitis, or simple conjunctivitis, which may be divided into (a) *acute,* often infectious (frequently epidemic) increasing to the so-called Schwellungskatarrh; (b) *chronic,* with all the intervening forms between simple hyperemia of the conjunctiva, or conjunctivitis sicca, up to the chronic secretion of advanced forms. It arises independently as an infection, as the manifestation of another, an underlying conjunctival disease, or through the influence of external irritation, chemical, thermal, or mechanical. Secondarily both forms may originate in diseases of the neighboring skin of the eyelid. Frequently enlarged follicles are seen, especially in the epidemic forms.

II. Conjunctivitis crouposa.

III. Conjunctivitis diphtheritica.

IV. Conjunctivitis blennorrheica (blennorrhea of the conjunctiva).

V. Conjunctivitis granulosa (trachoma).

VI. Conjunctivitis phlyctenulosa (eczematosa, lymphatica, scrofulosa).

VII. Conjunctivitis exanthematica, occurring in acute exanthemata of the skin.

VIII. So-called "spring catarrh," or vernal conjunctivitis.

IX. Conjunctivitis petrificans.

With these inflammations of the conjunctiva there are, as said before, often associated diseases of the cornea.

In regard to the infectiousness of diseases of the conjunctiva it may be remarked that every conjunctival secretion should be inspected, and that it is scarcely permissible to hold a secretion as not dangerous because a cover-glass smear discloses no micro-organisms. Also, a positive discovery is not conclusive of the danger of infection, since germs found in the inflammatory disease of one individual do not always set up an inflammation in another, and upon inoculation there often appear quite different forms than were in the original picture. Most important is the discovery of virulent diphtheria bacilli and of gonococci.

In regard to *treatment in general,* it is true that, so long as there are no complications involving the cornea, ice compresses generally give satisfaction, in conjunction with antiseptic solutions to prevent infection, of which the best are sublimate 1 to 5000, iodine trichloride 1 to 2500, boric acid 1.5 to 100 and oxycyanide of mercury 1 to 100.

After the original inflammation is gone, if tissue alterations remain, then the best things to use are nitrate of silver, sulphate of copper, and sulphate of zinc.

Besides the diseases already named there are others in the *region of the conjunctiva* as follows: 1. Wounds and their consequences, especially symblepharon. 2. Degeneration, such as (a) pinguecula, (b) pterygium, (c) amyloid, degeneration of the conjunctiva, (d) hyaline degeneration of the conjunctiva. 3. Hemorrhages into and from the conjunctiva. 4. Xerosis and spontaneous atrophy. 5. Ulcers, especially luetic and tuberculous. 6. Tumors. 7. Extension of skin diseases, as eczema, ichthyosis, pityriasis rubra and psoriasis. 8. Animal parasites, as cysticercus, filaria, etc.

As before stated, about thirty per cent. of all the affections of the eye falling under the care of the surgeon occur in the conjunctiva. Their relative frequency, however, varies greatly according to climate, latitude, race, general environment, and condition, being sometimes as low as ten per cent. and often as high as ninety per cent. The conjunctiva, being a mucous membrane, is subject to the pathological changes to which mucous tissues in general are liable, as well as to

some which seem peculiar to itself, and, being continuous with the mucous membranes of the upper air-passages, is apt to participate, by continuity, in the inflammatory processes to which the nasal and post-nasal tissues are subject. It is also, on account of the vascular connections, almost without exception implicated to a greater or less degree in the inflammations of the anterior part of the eyeball,—keratitis, iritis, and cyclitis. It seldom takes part in inflammatory affections of the choroid or the retina.

Inflammations of the conjunctiva are characterized by hyperemia, abnormal amount of secretion, which may vary from lachrymation to the production of mucus or pus; pain, which may be slight or severe; and photophobia. Conjunctivitis exists where the presence of an abnormal secretion is added to hyperemia. Almost all forms of conjunctivitis are contagious, though the transmission of secretion from a diseased to a normal eye does not result in a definite and constant pathologic entity. The same secretion, obtained from an eye the seat of conjunctivitis, may be inoculated into several healthy eyes and produce a different clinical picture in each. Hence it is supposed that the type of inflammation set up is influenced by other than bacterial cause. The rôle of the toxins in inflammatory processes offers an inviting field for study. So long as the protective epithelium of the conjunctiva and cornea is intact, the patient is comparatively safe from microbic invasion (Randolph).

To those ophthalmologists who have not at hand the conveniences of a laboratory, with culture media and incubators, etc., the following statistics (Browning, *Ophthalmic Review*, April, 1912), derived from 1,000 consecutive cases of conjunctivitis, may be of interest. The results indicate the amount of reliance to be placed on smear preparations when cultivations cannot be made. All these cases were examined by direct smears made on slides, and at the same time cultures were made on suitable media. Human blood agar was used in every case throughout this examination, as all the ordinary eye organisms grow well on it, whilst it has been found quite the best medium for growing the Koch-Weeks bacillus and the gonococcus, and is of considerable assistance in differentiating the pneumococcus from streptococcus longus. The other media used were nutrient agar, blood serum and broth. The clinical diagnosis was not made in many of the cases by the surgeon until the bacteriological findings were reported, so that it was impossible to compare the clinical diagnosis with the organism found on bacteriological investigation. In the cases of ulceration of the cornea which are included in this list, where possible, the smears and cultures were made from scrapings from the edge of the ulcer.

Browning does not in any way wish to suggest that cultivations should not always be made where possible, as this is absolutely essential for the confirmation of the presumptive diagnosis made from the direct smear.

The following table shows the percentage of cases in which the organism was found in the direct smear and subsequently confirmed by culture:

TABLE I.

Organism.	Presumptive diagnosis.	Presumptive diagnosis confirmed.
Gonococcus	86.5	59.4
B. lacunatus (Morax)	59.4	32.6
B. ægypticus (Koch-Weeks bacillus)	86.0	41.2
Pneumococcus	60.0	45.3
B. diphtheriæ	61.5	61.5
B. pneumoniæ	20.0	20.0
Streptococcus longus	8.0	8.0

In making the direct smears the following was the technique employed: The lower lid was everted and a platinum loop, sterilized by heating to redness in a flame and allowed to cool, was drawn across the fornix, gathering up any beads of pus or mucus present. The material thus obtained was spread on glass slides in a fairly thin film. Lumps of pus were broken up with the loop and spread evenly. Whenever possible two slides were made, and one stained by carbol methylene blue and the other by Gram's method counter-stained with neutral red. If very little exudate could be obtained, only sufficient for one slide, the film was stained by methylene blue, as micro-organisms are more readily demonstrated in the films stained by carbol methylene blue than in those stained by Gram's method. The methylene blue specimen was then examined microscopically with a 1/12 inch oil-immersion lens, and very often it was possible to make an immediate provisional diagnosis. In a considerable number of cases a presumptive diagnosis can be arrived at without having recourse to the Gram stain, provided that the observer is familiar with the morphology and pleomorphism of the various eye organisms; whilst in others the evidence obtained from the Gram slide is invaluable. Morax-Axenfeld diplo-bacillus, Koch-Weeks bacillus, pneumococcus, bacillus xerosis, gonococcus, staphylococci and Friedlander's pneumo-bacillus can often be differentiated at once by the microscopical examination alone. It is often difficult or impossible

to differentiate the streptococcus from the pneumococcus, and probably many of the organisms in the eye diagnosed as pneumococci are really streptococci, the crucial test being animal inoculation. In several of the cases diagnosed as pneumococcal the organism recovered from the heart blood of the experimental animal proved to be the pneumococcus. Other strains, while reacting on the sugars and possessing the fermenting reactions of pneumococci, failed to provoke a pneumococcal septicemia in the rabbits. However, these have been recorded as pneumococci. It will be seen from the foregoing table that in a very large number of cases the pathogenic organism found in the smear was identical with that found by culture. Again, in some cases, notably in those of Koch-Weeks infection, the smears gave more useful information, as regards the infecting organism, than the culture. This result is partly due to the difficulty of growing Koch-Weeks bacillus, and partly to the antiseptics so often used in the eyes of the patient before being seen by the bacteriologist, the antiseptic being present in sufficient concentration to inhibit the growth of the organism on the artificial medium, but not preventing its increase in the living tissues of the conjunctival sac. There were very few cases of gonococcal infection in which the diagnosis could not have been definitely made without resort to cultivation. In some cases the finding in the culture was different to that in the direct smear. This may have been due to errors of observation or interpretation of the microscopical examination. On many occasions a definite diagnosis could not be given upon examination of the direct smear, and some such report as "a Gram positive diplococcus" was sent out. The total number of different organisms found was 18. In several cases the organism was one of the so-called non-pathogenic germs, occasionally in some the organism in pure culture, and the patient rapidly improved when autogenous vaccine was used; for example, the two cases in which bacillus proteus was found and an autogenous vaccine used with satisfactory results. In the cases diagnosed as tubercle and diphtheria, the organism was proved by animal inoculation, and in the case of diphtheria complete cultural examinations were also made.

DIPLOCOCCUS GONORRHEÆ.

1. Total cases	89
2. Presumptive diagnosis based on film direct	78
3. Presumptive diagnosis confirmed by culture	53
4. Organism present in culture, not detected in film	11
5. Potential error, *i.e.*, presumptive diagnosis unsupported by cultural results	25

In one case the diagnosis was made as "Gram negative coccus" in the direct, and in another case as "cocci present." In both these cases gonococci were found in the culture.

BACILLUS LACUNATUS (MORAX-AXENFELD).

1. Total cases 190
2. Presumptive diagnosis based on film direct.................. 112
3. Presumptive diagnosis confirmed by culture................. 62
4. Organism present in culture, not detected in film............. 78
5. Potential error, *i.e.*, presumptive diagnosis unsupported by cultural results 50

The considerable number of cases (28) in which the organism was found direct and not in the culture, was due to the fact that the cultures remained sterile after three days' incubation, probably owing to the presence of antiseptics in the eye. No attempt was made to differentiate between Petit bacillus and Morax-Axenfeld bacillus. Every case was transferred from the blood agar to blood serum to test its liquefying power on this latter medium.

BACILLUS ÆGYPTICUS (KOCH-WEEKS BACILLUS).

1. Total cases 163
2. Presumptive diagnosis based on film direct.................. 142
3. Presumptive diagnosis confirmed by culture................. 66
4. Organism present in culture, not detected in film............. 23
5. Potential error, *i.e.*, presumptive diagnosis unsupported by cultural results 76

Again the considerable number of cases in which the organism was found in the direct and not in the culture was due to the fact that the culture remained sterile. In four cases cultures were not made.

DIPLOCOCCUS PNEUMONIÆ (PNEUMOCOCCUS).

1. Total cases 64
2. Presumptive diagnosis based on film direct.................. 39
3. Presumptive diagnosis confirmed by culture................. 29
4. Organism present in culture, not detected in film............. 25
5. Potential error, *i.e.*, presumptive diagnosis unsupported by cultural results 10

Four cultures remained sterile.

BACILLUS DIPHTHERIÆ (KLEBS-LOEFFLER BACILLUS).

1. Total cases 13
2. Presumptive diagnosis based on film direct.................. 8

3. Presumptive diagnosis confirmed by culture 8
4. Organism present in culture, not detected in film 5
5. Potential error, *i.e.*, presumptive diagnosis unsupported by cultural results .... nil.

All these cases except one were proved by guinea-pig inoculation and by fermentation tests. They occurred over a period of about two and a half years.

The staphylococci must be grouped in a somewhat different manner, as it is impossible, except in a few cases, from an examination of a direct smear, to say that the Gram-positive coccus present belongs to the staphylococcus group: for the streptococci, sarcinæ and other organisms are as a rule indistinguishable from the staphylococci in the Gram-stained smear.

Many of the cases in which staphylococci alone were found in culture were from eyes examined before operation in which there was some conjunctivitis present.

STAPHYLOCOCCUS PYOGENES AUREUS.

1. Total number of cases 149
2. Aureus alone in culture, nil direct 104
3. Aureus in culture with other organisms 55
4. Provisional diagnosis of staphylococcus 10
5. Provisional diagnosis of cocci 28

In most of the cases no organism could be found direct

STAPHYLOCOCCUS PYOGENES ALBUS.

1. Total number of cases 250
2. Albus alone in culture, nil direct 104
3. Albus with other organisms in culture 146
4. Provisional diagnosis of staphylococcus 24

Staphylococcus albus was nearly always found associated with bacillus xerosis, especially in those cases examined before operation.

No attempt was made to differentiate staphylococcus albus from micrococcus candicans or staphylococcus epidermidis albus.

STAPHYLOCOCCUS PYOGENES CITREUS.

1. Total number of cases 25
2. Present in pure culture 8
3. Present with staphylococcus albus 4
4. Present with staphylococcus aureus 4
5. Present with albus and aureus mixed 6

The staphylococcal cases do not include those mixed cases in which a diagnosis of gonococcus, Koch-Weeks or other specific micro-organism was made from the examination of the direct smear or by culture.

DIPLO-BACILLUS PNEUMONIÆ (FRIEDLANDER PNEUMO-BACILLUS).

1. Total number of cases	15
2. Presumptive diagnosis from direct smear, confirmed by culture	3
3. Present in culture	15

STREPTOCOCCUS PYOGENES LONGUS.

1. Number of cases	24
2. Presumptive diagnosis confirmed by culture	2
3. Present in culture	24

B. proteus was found in culture on eight occasions, in three cases in pure culture. Two of these cases were treated with autogenous vaccines, and did very well. On no occasion was it diagnosed in the direct, though twice it was diagnosed as doubtful Koch-Weeks.

Diplococcus intracellularis meningitidis was found in one case in an adult, diagnosed as a Gram-negative coccus direct, found to be meningococcus by cultivation and sugar reactions.

Micrococcus catarrhalis occurred in pure culture on two occasions, otherwise it was only found mixed with organisms of greater virulence.

Bacillus tuberculosis. One case of Parinaud's conjunctivitis was examined direct and by animal inoculation. Tubercle bacilli were found in the local lesion and glands of the guinea-pig.

Bacillus coli communis was found in one case in the fluid drawn off from the anterior chamber of the eye.

Bacillus mesentericus was found seven times in culture with other organisms.

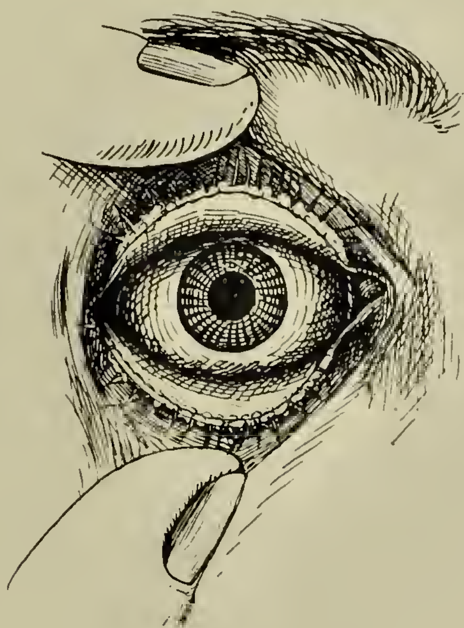
Bacillus subtilis was found six times with other organisms.—(C. P. S.) See also **Bacteriology of the Eye**, Vol. II, page 763, and the various forms of **Conjunctivitis** as alphabetically arranged in this *Encyclopedia.*

Conjunctivitis, Acute catarrhal. CATARRH OF THE CONJUNCTIVA. SIMPLE CONJUNCTIVITIS. CATARRHAL OPHTHALMIA. This may be regarded as an aggravated form of hyperemia of the conjunctiva, generally due to infection and chiefly characterized by a mucous or muco-purulent discharge. (See figure.)

It may also be a symptom of various exanthemata—measles, scarlet

fever, small-pox—in which it is sometimes called exanthematous conjunctivitis.

The disease usually begins with sensations of smarting and burning of the lids and a feeling of sand in the eye. The discharge, at first serous, soon becomes muco-purulent and accumulates in the form of flakes in the retrotarsal folds. The lids stick together in the morning, while dried secretion is found adhering to the margins of the lids and to the eyelashes. The conjunctival lining of the lids is also seen to be slightly swollen and red. As evening approaches there is increased



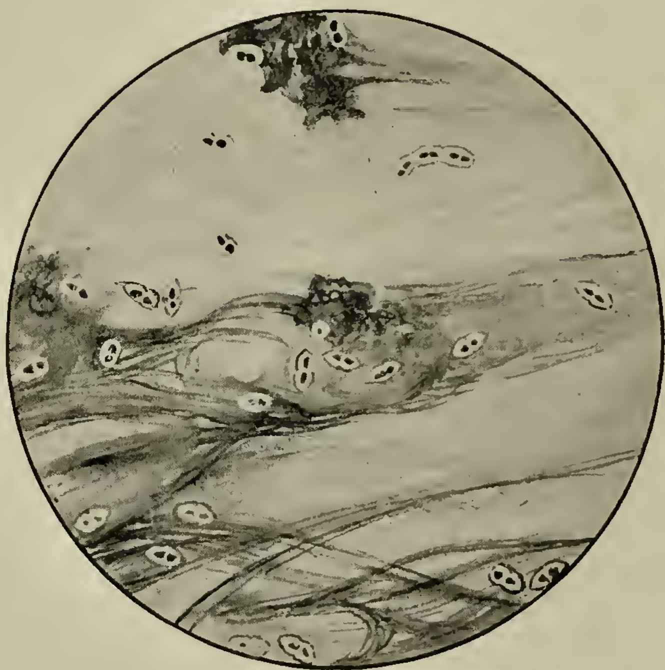
Catarrhal Conjunctivitis.

discomfort, accompanied by some photophobia in the bright sunlight or when in a lighted room. Lachrymation is usually present, the tears carrying off some of the discharge.

The conjunctival vessels on the globe are in most cases enlarged, but, in the milder types, there is no marked redness of the ocular conjunctiva, the thickening and redness being confined to the palpebral portion of the membrane, particularly at the junction of the lids and the eyeball in the retrotarsal folds. Sometimes there is a slight chemosis present, in which case the nutrition of the cornea is liable to suffer, and ulceration may take place not only from pressure upon the vessels in that region, but, following infection, from the discharge retained in the sulcus.

The mechanical and traumatic varieties of simple conjunctivitis result from the presence in the cul-de-sac of small foreign bodies such

as dust, pollen, insects, etc. Scrofulous subjects and persons having folliculosis are particularly susceptible to this disease. Streptococci, staphylococci, and pneumococci are present in severe cases. According to Gifford, the pneumococcus of Fraenkel is a common cause of simple conjunctivitis. On the other hand Morax and Parinaud regard this bacterium as an infrequent cause of this form of conjunctival inflammation. The pneumococcus of Fraenkel (known as the diplococcus pneumoniæ of Weichselbaum, micrococcus lanceolatus of Talamon, and micrococcus Pasteuri of Sternberg) is in the form of oval cocci, often



Pneumococci.

arranged in pairs or chains, with the free ends often pointed and encapsulated. (See figure.)

Infection of the conjunctiva undoubtedly takes place also from inoculation of animal matter of the kind which is found around slaughter-houses (Despagnet). The inflammation is limited to one eye, and consists of a kind of glandular swelling of the conjunctiva with granulations which exude pus on pressure. There is also more or less swelling of the parotid and cervical glands. The cornea is not usually affected. It is most probably microbic in origin, though the microbe has not been identified.

Under this same heading should be placed the conjunctivitis, which, however, is of the chronic form, which we find associated with obstruction of the lachrymal apparatus, even when there is no purulent

inflammation of the sac, the so-called *lachrymal conjunctivitis.* The secretions which should find their exit through the nasal duct are thought by some to be decomposed and form a pabulum for the growth of some of the numerous microbes which enter the eye from the air.

The diagnosis is generally an easy matter. If in doubt, a microscopic examination will be conclusive. The prognosis is generally favorable.

In treating this condition the cause should be searched for and all sources of irritation removed. Mild antiseptics should be used for cleansing purposes, such as boric acid (gr. 15 to oz. i), or bichloride of mercury 1 to 10,000. Cold applications should be used every two or three hours, to be followed by the instillation of four or five drops of the boric acid solution. At night a mild antiseptic ointment should be applied to the lid margins.

As the acute stage of the disease subsides more stimulating lotions may be used with advantage. A one-half of one per cent. solution of nitrate of silver painted on the lids is most beneficial.

Cleanliness is an important factor in treatment. Smoked glasses should be prescribed. *Poultices of any kind are absolutely contraindicated in all forms of conjunctivitis.* After recovery, the condition of the refraction should be investigated, and ametropia, if found, should be corrected.

Conjunctivitis, Acute contagious. KOCH-WEEKS CONJUNCTIVITIS. EPIDEMIC CONJUNCTIVITIS. ACUTE MUCO-PURULENT CONJUNCTIVITIS. "PINK-EYE." This may be the stage of resolution following an acute hyperemia of the conjunctiva, or a distant pathological process due to a specific cause unconnected with a catarrhal condition of the upper air-passages. It is a common accompaniment of epidemic influenza, acute coryza, hay-fever, and the exanthemata, and may be idiopathic from exposure to atmospheric changes. It has a definite period of incubation. It is accompanied by a muco-purulent discharge, and both eyes are usually affected. The disease is more common in the spring than in the fall months, is often epidemic, is not limited to any country or climate and occurs at all ages except possibly during the first ten days of life. It seems probable that the conditions of hyperemia and congestion of the conjunctiva only furnish a good field for the activity of some infecting germ. The condition known as "pink-eye" is the type of this form of conjunctival inflammation, and the fact that it is highly communicable renders the existence of a specific germ certain. In 1883 Koch in Egypt was the first to recognize this bacillus, but he did not pursue the question further. Weeks in 1886 was able to make pure cultures of

this bacillus, and he inoculated healthy conjunctivæ with them and produced the disease, the secretion from which, in its turn, produced the disease in other eyes. Hansell in 1886, Kartulis in 1887, and Morax in 1894 made confirmatory investigations. Others (Axenfeld, Morax, Gifford) have found the pneumococcus in the secretion of acute conjunctivitis, and regard it as the pathological agent. This germ is often found in the healthy lachrymal sac, and it is argued that some change in the local conditions renders it virulent. Pink-eye affects the lower animals as well as man.

The Koch-Weeks bacillus stains readily with analin dyes and is often associated with the xerosis bacillus. (See figure.) It somewhat resembles the bacillus of mouse septicemia. Gifford found the pneumococcus in 36 out of 40 cases, and Junius met with it in 49 out of 60 cases. In 31 of the 60 cases examined by Junius the pneumococcus was found in a pure state; in 18 it was associated with the staphylococcus or with the xerosis bacillus. Veasey has recently demonstrated that for Philadelphia and vicinity the most frequent cause of acute catarrhal conjunctivitis is the pneumococcus of Fraenkel. Of 64 cases examined by this observer, the pneumococcus was present in 52. In 10 of these the pneumococcus was mixed with other bacteria, and in only three of the cases was the Koch-Weeks bacillus present. Those cases in which the micrococcus pyogenes albus or aureus was present were mild in character.

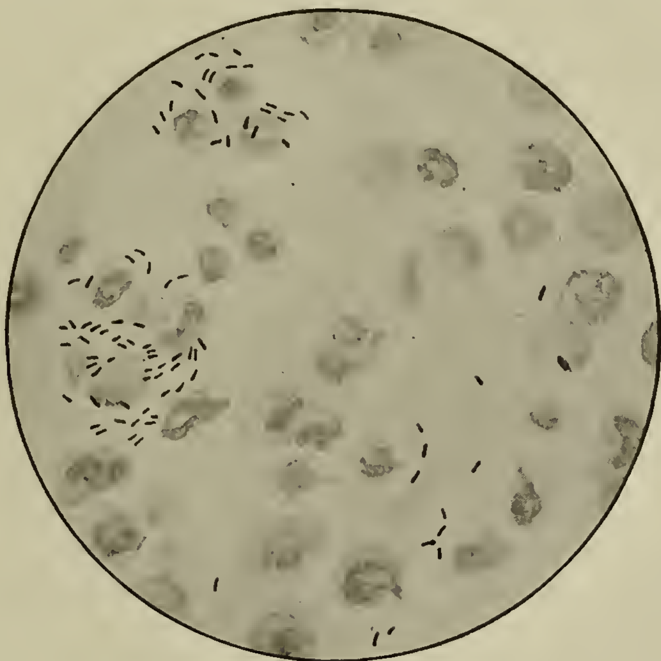
The susceptibility to conjunctival infection of all kinds is much more pronounced in children and infants than in adults.

That acute conjunctivitis is caused by various infectious material cannot be doubted. Cases have been observed among girls of from two to six years of age, where the infection seemed to come from the discharges of the genitalia of the female, not specific, though some hold that the gonococcus is to be found in all of them. Infection of the conjunctiva also undoubtedly takes place from inoculation of animal matter. See **Parinaud's conjunctivitis.**

An almost pure infection of marked virulence, leading to perforating corneal ulcer in spite of treatment, is noted by Cunningham (*British Med. Jour.*, July 20, 1907) in an infant 2 years old. In the early stages it resembled acute epidemic conjunctivitis. There was a semi-purulent eruption on the face, suggesting autoinoculation. The right eye was not affected during the whole course of the disease. The parotid and posterior cervical glands were enlarged. There were no signs of Parinaud's conjunctivitis which the adenopathy suggested. Uhthoff has described a somewhat similar class of cases due to the streptococcus and complicated with impetigo of the face.

Traumatic conjunctivitis results from blows, the lodgment of foreign bodies, the action of chemicals, the irritating effect of dust (found among millers, masons, etc.), the effect of exposure to bright light (electric welding, snow-blindness), and repeated exposures to the X-rays. A severe form of the disease is observed in gas-fitters. In all these cases, however, photophobia, lachrymation, pain, and swelling are likely to be symptoms of unusual prominence, and edema of the lids and superficial corneal ulceration are common. (Ball.)

Exanthematous conjunctivitis is found in connection with eruptive diseases, particularly rubeola. In the form of conjunctivitis known



Koch-Weeks Bacillus.

as *vesicular catarrh,* the tarsal conjunctiva is covered with numerous small elevations which Arlt compared to the appearance of fine sand scattered on a moist glass plate. *Pustular conjunctivitis* is a rare form in which pustules appear on the bulbar conjunctiva and leave small grayish or yellowish ulcers.

Metastatic gonorrheal conjunctivitis is a mild form of catarrhal inflammation, found in gonorrheal or gleety subjects, who have joint complications.

There is a form of acute conjunctivitis, or rather, hyperemia of the conjunctiva found after the insufflation of calomel into the eye while some of the iodides are being administered internally. This is called *mercuric-conjunctivitis,* and is supposed to be due to the formation of an iodo-mercuric compound, which is highly irritating. For this

reason all forms of mercuric application to the conjunctiva should be abstained from during the internal administration of the iodides.

The symptoms of the disease begin to manifest themselves within a day or two after infection, by a smarting of the eyelids. The conjunctiva is hyperemic and the eye looks red and swollen. As the discharge increases and dries the lashes become glued together. The character of the discharge begins in a day or two to change. From having been watery it becomes mucous, or possibly muco-purulent in quality. If the lower lid is pulled down a roll or some flakes of mucus will be seen lying in the lower fornix. In severe cases which take on a more purulent form, small hemorrhages in the conjunctiva are frequently observed, a pseudo membrane may appear and in the absence of a bacteriologic examination, such cases may be mistaken for diphtheritic conjunctivitis. The pain is usually slight, and confined to the eye and does not radiate to the surrounding parts like the neuralgic pain of iritis. More or less photophobia is usually present, which may be much more intense if the epithelium of the cornea is involved. Patients often complain of a sensation of a foreign body in the eye. Vision is impaired, partly from a maceration of the corneal epithelium, and the smearing of the discharge itself over the cornea. Use of the eyes causes pain. In three or four days the disease usually reaches its height. If the bulbar conjunctiva is greatly involved, with a large serous exudation lifting it up around the cornea the condition is called *chemosis*.

The disease tends to recovery in from five to ten days.

In almost all cases both eyes are affected, the inflammation in one usually beginning while the disease is at its height in the other.

The bacteriologic diagnosis depends on the finding of the pneumococcus or the Koch-Weeks bacillus. Clinical diagnosis is usually sufficient; the presence of a discharge, the location of the greatest redness in the region of the fornices, and the character of the secretion, in the vast majority of cases, will enable the practitioner to make a diagnosis without difficulty. Iritis may exist and be overlooked during an attack of acute catarrhal conjunctivitis.

Most cases of acute conjunctivitis, when the infection is not severe, go on to recovery with no other treatment than care and cleanliness, and these are the means to be employed in the beginning. No attempt should be made to abort the process, and leeching is seldom called for. All forms of poulticing are to be avoided, and nothing should be applied to the eyes which will prevent the speedy exit of the discharge. The patient should be placed in proper surroundings, where the air is pure and free from dust, and the eyes protected from strong light by

smoked glasses. The use of tobacco and alcohol should be forbidden while he is under treatment. During the hyperemic stage the eyes should be bathed frequently in hot water. If there should be marked edema and chemosis, the application of cold compresses for a few minutes at a time will be more beneficial than the heat. To prevent the gumming together of the lids during the night, the edges should be anointed with vaseline at bed-time. When the secreting stage sets in, the use of mild astringents should be begun. A solution of nitrate of silver, two grains to the ounce, should be applied to the everted lids once a day. A solution of five grains to the ounce is used by some in severe cases, but this strength is not usually called for. Between the daily treatments by silver, mild astringent collyria can be used with benefit. For the past few years argyrol and protargol have been used extensively by many surgeons in conjunctival inflammations. These preparations possess no advantages over silver, except that their application is not painful. They are used in 5, 10 and 20 per cent. strength solutions. Largin in 10 per cent. strength is highly recommended by Sydney Stephenson as a substitute for nitrate of silver. Sulphate of zinc (gr. j to ℥ j) is a valuable astringent and can be used three times a day. Acetate of lead (gr. j to ℥ j) is a very good remedy, but must not be used where there is any danger of an abrasion of the corneal epithelium, as a deposit of lead carbonate would leave a white opacity that might seriously impair the vision. A 10 per cent. solution of cuprol, applied once daily, has been recommended, though this preparation has been found unsatisfactory by some. In prescribing collyria, Thompson asserts that distilled water acts injuriously on the epithelial cells, and for this reason it is better to use filtered water. Where there is severe pain, a few drops of holocain can be used, or, if the pain is due to corneal infiltration, atropin. Holocain, in ½ per cent. strength solution, is much better than cocain, which acts injuriously on the corneal epithelium. If chemosis is great, the swollen conjunctiva should be anesthetized and numerous punctures made in it with a cataract knife.—(C. P. S.)

Conjunctivitis, Acute muco-purulent. See **Conjunctivitis, Acute contagious.**

Conjunctivitis, Adenomatous. A condition called adenomatous conjunctivitis by Clark, for the want of a better name, may be mistaken for the so-called brawny trachoma of Stellwag. It is occasioned by a prolonged non-specific irritation superimposed on an individual idiosyncrasy. It is confined to the retrotarsal fold, and is characterized by a hypertrophy of the normal lymphoid follicles of that region, which assume a frog-spawn-like aspect. In this condition

there is no infiltration, consequently no cicatrization. Under suitable treatment this condition may be relieved without leaving the distinctive traces of trachoma.

The brawny trachoma of Stellwag is simply a coalescence of trachoma follicles into distinct masses in a conjunctiva already richly infiltrated with lymphoid cells. Other usual characteristics of trachoma are also present, notably, infiltration and thickening of the conjunctiva.

Conjunctivitis Ægyptiaca. (L.) A purulent conjunctivitis; so called because of its prevalence in Egypt and northern Africa. See **Trachoma.**

Conjunctivitis aphthosa. (L.) PUSTULOUS OPHTHALMIA. APHTHOUS CONJUNCTIVITIS. A form of conjunctivitis in which the vesicles are distinctly larger than in simple phlyctenular conjunctivitis. See **Conjunctivitis phlyctenulosa maligna.**

Conjunctivitis artificialis. (L.) Under this classification Peters designates that form of conjunctivitis produced intentionally, by the introduction into the conjunctiva of some material, which either of itself or from its chemical action, causes an irritation, for the purpose of influencing the conjunctival condition. See, also, **Conjunctivitis, Traumatic.**

Conjunctivitis, Ascarides. Ascaris-conjunctivitis is a form of acute inflammation of the conjunctiva, caused by the action of the cœloma fluid expressed from the skin-muscle-tube, intestines and sexual apparatus of ascaris lumbricoides (ascaris megalocephala) on the conjunctiva. Ophthalmological literature contains only two references, while Goldschmidt collected about 20 cases furnished by zoologists while preparing ascarides for scientific purposes.

Doff (*Klin. Monat. f. Augenheilk.*, December, 1912) reports two cases, and his experiments with the fluid on persons and animals gave the following results: The cœloma fluid of the ascarides contains a substance which in especially predisposed individuals, if brought into the conjunctival sac, may immediately produce very violent inflammatory phenomena; intense chemosis with lachrymation and burning, swelling of the lids, so that the palpebral fissure may be covered. After from 12 to 24 hours the inflammation subsides, and the eye is again normal in from 3 to 4 days. The cornea and deeper structures remain intact. If the instillation is repeated the inflammatory changes decrease in intensity, similarly to the action of dionin. The susceptibility varies according to the species of animals and according to individuals. All transitions from complete immunity to the highest degree of hypersensitiveness are en-

countered. The susceptibility cannot be modified by ingestion or withdrawal of lime. The inflammatory phenomena are not elicited by reflex, as anesthesia of the conjunctiva does not prevent them. The point of attack by the cœloma fluid is probably the vascular wall, since its effect cannot be checked by adrenalin. Hence it belongs, with a series of animal and vegetable poisons (tuberculin, pollen toxin, etc.), to the group of specific vascular poisons, characterized by the common property that they only act in specially predisposed individuals. Its action probably is that of an alkaloid, perhaps the one found by Flury which acts like sepsin. The effect of the cœloma fluid is not changed by its passage through bacterial filtra.—(C. P. S.) See, also, **Conjunctivitis, Toxic.**

Conjunctivitis, Atropine. See **Conjunctivitis, Toxic.**

Conjunctivitis, Autumnal. Said to be an aggravated type of catarrhal conjunctivitis coming during the middle or latter part of August. All the symptoms of a catarrhal conjunctivitis are exceedingly pronounced. As a rule, there is more or less nasal catarrh associated with it. It is probably identical with "pink eye" and due to infection from the Koch-Weeks bacillus.

Conjunctivitis, Bacteriology of. The present state of knowledge unfortunately does not admit of an accurate classification of the various forms of conjunctivitis upon a pathological basis. In only a few cases, as pointed out by Parsons, is it possible to specify a definite microorganism as the *causa causans* of a given clinical type of inflammation. Nor is this surprising when we consider the multitudinous factors at work. The interaction and reaction of organism and tissue, with the modifying influences of toxicity and immunity—relative or absolute—cannot be too often or too forcibly insisted upon. As Parsons very aptly says, "The pathologist too readily imagines that his experiment *in vitro* will be unchanged *in corpore vili,* whilst the clinician expects all his difficulties to be solved by a film or a culture-tube. When we add to these distracting factors the phenomena of mixed infections, the bewildering complexity of the subject is complete.

It is therefore necessary to treat the bacteriology of conjunctivitis apart from the clinical types, and incidentally to collate the two and, as far as is possible, show their true relationships."

The systematic bacteriologic examinations by O. Kuffler (*Zeitschr. f. Augenheilk.,* 1909, XXII, p. 405) of 727 cases of conjunctivitis showed that 64 per cent. yielded positive, 36 per cent. negative results, viz.: diplobacilli, 306 = 42 per cent.; diplobacilli and pneumococci, 26 = 4 per cent.; pneumococci, 55 = 8 per cent.; xerosis, 41 = 6 per cent.; staphylococci, 13 = 2 per cent.; gonococci, 7 = 1 per cent.; diphtheria,

5 = 1 per cent.; pneumobacillus, 1; negative, 274 = 36 per cent. The clinical findings in the negative cases were: acute simple conjunctivitis, chronic conjunctivitis apparently caused by chemical, thermic or mechanical irritations, and follicular catarrh.

The probable diagnosis of diplobacillus conjunctivitis in most cases could be inferred from the clinical picture, which proves the predominating correspondence between the clinical aspect and the bacteriologic condition of this disease: small grayish lumps of secretion at the inner angle; slight changes in the epidermis of the lids and their margins. The subchronic and chronic cases exceeded by far the acute ones, in accordance with the views of Axenfeld. It was less frequent in children than in adults, not epidemic, but endemic in the same families.

Pneumococcus conjunctivitis was characterized by intense injection of the ocular conjunctiva, slight ciliary injection, petechiæ, and, in less marked cases, the occurrence of slight superficial pseudomembranes.

In 5 out of 6 cases of diphtheritic conjunctivitis Loeffler's bacillus could be cultivated. One case is reported in detail, to show how difficult the bacteriologic examination sometimes may be if in mixed infections other micro-organisms predominate. With regard to the treatment, the writer recommends injections of antitoxin without waiting for proof of the presence of diphtheritic bacilli. Kuffler fully recognizes the value of bacteriologic examinations of all cases of conjunctivitis, but states that they do not admit of a classification of the different forms of conjunctivitis, which still depends on anatomic and clinical features.

The majority of the 40 cases of dacryocystitis showed, in accordance with other authors, pneumococci as the cause of infection. In three cases of panophthalmitis, the bacillus subtilis was found in 2 exclusively, and in 1 with pneumococci; 3 were caused by pneumococci, and 1 by streptococcus mitior.

In an instructive article on this subject, McKee (*Amer. Jour. Med. Sc.*, June, 1906) remarks that the work begun by Axenfeld, Uhthoff, Morax, Weeks and Gifford has borne such fruit that the old classification of conjunctivitis, according to clinical features, into catarrhal, purulent, membranous, granular, phlyctenular, with their subdivisions, is passing, and today the different forms are receiving their names according to pathologic and bacteriologic findings. While we are still unable to bring all cases of conjunctivitis under this classification, it enables us to divide conjunctivitis into two groups: 1. Conjunctivitis with no known bacteriologic cause, a conjunctivitis from foreign bodies, errors of refraction, trachoma, follicular conjunctivitis, spring catarrh.

2. Conjunctivitis with a definitely known bacteriologic cause, as blennorrhea from the gonococcus, streptococcus, pneumococcus, bacillus coli communis, conjunctivitis from Morax-Axenfeld's diplobacillus, Koch-Weeks bacillus, pneumococcus, bacillus of diphtheria, streptococcus, bacillus of influenza and pseudo-gonococcus.

Duane has discussed (*N. Y. Med. Jour.,* May 26, 1906) the symptoms presented by the various bacteriologic types of conjunctivitis, founded upon the careful examination of 132 cases of acute conjunctivitis. The conclusions arrived at as a result of the study of these cases are (verbatim) as follows: 1. There is no special type of conjunctivitis associated with any special germ. The clinical picture, therefore, affords no clew to the germ causing the conjunctivitis. 2. While certain organisms, like the gonococcus, diphtheria bacillus and streptococcus, usually cause severe reaction, and the other germs regularly produce much slighter effects, this rule has many exceptions, and no sure deductions can be drawn from the intensity of the inflammation as to the germ causing it. 3. Membranous conjunctivitis, as is well known may be caused by a variety of organisms. It does not necessarily indicate a severe inflammation, nor one that will always produce other evidences of excessive reaction besides the false membrane. 4. In trachoma, particularly trachoma in the stage of acute exacerbation, a variety of organisms may be present. These do not, of course, cause the trachoma, but they are of importance in that they do produce an intercurrent acute conjunctivitis with secretion, which latter serves as a carrier of contagions and thus disseminates not only the conjunctivitis, but the trachoma as well. 5. The staphylococcus albus, and particularly the staphylococcus aureus, when occurring in the conjunctival sac, are sometimes at least pathogenic, and distinctly predispose to the production of corneal lesions. The fact that the staphylococcus albus is probably an almost constant inhabitant of the conjunctival sac does not invalidate this conclusion.

Very mixed infections seem, if anything, to be rather less severe than those in which one germ is the predominating infecting agent.

In presenting these conclusions Duane says that he does not attach too much importance to the bacteriologic findings, and that the latter are often uncertain and negative; that staphylococci, when found in old cases, particularly in the corneal lesions, represent not the primary infecting germ, but a secondary invasion, so that they are to be regarded not as the cause of the lesion, but simply as a complication of it or as a mere contamination; and, finally, that deductions as to the action of the pathogenic germs must reckon not only with the kind of germ present, and with its

amount, but also with its varying pathogenicity.—(C. P. S.) See, also, **Bacteriology of the eye** in Vol. II of this *Encyclopedia.*

Conjunctivitis blennorrhagica. (Seu blennorrheica.) (L.) Purulent conjunctivitis. An acute inflammation of the conjunctiva which begins either in the retrotarsal fold or palpebral portion, and is characterized by great swelling, redness, and infiltration of the tissues of the lid, great œdema of the conjunctiva, both ocular and palpebral, great heat and pain, some rise of the general temperature, and a profuse purulent discharge. The complications are ulcer, slough, or abscess of the cornea, prolapse of the iris, and sometimes purulent panophthalmitis. It is markedly contagious by contact with the secretion. See **Conjunctivitis, Purulent.**

Conjunctivitis blennorrheica. (L.) See **Conjunctivitis, Purulent.**

Conjunctivitis blennorrheica neonatorum. (L.) Ophthalmia neonatorum. Purulent ophthalmia occurring in new-born children; generally due to infection from the genital canal of the mother. See **Conjunctivitis, Purulent.**

Conjunctivitis bulbi. (L.) Ocular conjunctivitis. Conjunctivitis confined to the ocular conjunctiva.

Conjunctivitis, Catarrhal. See **Morax-Axenfeld conjunctivitis**, also, **Conjunctivitis, Sub-acute catarrhal.**

Conjunctivitis catarrhalis. (L.) Catarrhal conjunctivitis. A catarrhal or simple conjunctivitis, with a more or less free discharge of mucus or muco-pus, redness and swelling of the palpebral and occasionally of the ocular conjunctiva, some swelling of the lids, and a burning, smarting pain. See **Conjunctivitis, Acute catarrhal.**

Conjunctiva, Catarrh of the. See **Conjunctivitis, Acute catarrhal.**

Conjunctivitis, Chalazion. This is a rather uncommon, chronic, often bilateral, obstinate, conjunctivitis of the follicular type, presenting no special bacteriological phases, but always associated with multiple chalazia. It is something more than a conjunctival injection associated with an accidental number of Meibomian cysts; the two diseases appear to be due to a common cause and get better or worse at the same time. The curetting of the small cysts as they appear, the frequent use of simple, soothing collyria—after fomenting the eyes with very cold water—and the massage of the lids with brown ointment once or twice daily seems to give the best results. Careful bacterial tests should be made from time to time. It occasionally happens that the Morax-Axenfeld bacillus seems responsible for the disease.

Conjunctivitis, Chronic. This is a common disease in the aged, characterized chiefly by hyperemia, swelling of the caruncle, hypertrophy of the papillary layer of the conjunctiva, and a scanty muco-purulent

discharge. It may be the result of an acute catarrhal conjunctivitis, or of an error of refraction, of lachrymal disease, of nasal inflammation, of excessive near work, or of unhygienic surroundings. The treatment includes the removal of the cause, abandonment of injurious habits (smoking, abuse of alcohol, etc.), correction of errors of refraction, and attention to the general health. (Ball.)

A tedious form of conjunctivitis is sometimes observed during the progress of those forms of disease in which the products of tissue-change are not properly eliminated. Gout is a typical representative of this form of disease. Associated with the conjunctivitis there are nearly always, after a time, superficial infiltrated portions of the cornea, and sometimes with the involvement of the underlying sclera. There is not usually any considerable mucous secretion. The attacks continue, with recurrences, sometimes for two or three months, and the exacerbations are commonly associated with changes in the meteorological conditions. Mere local treatment is ineffective if the diet and mode of life are not regulated. A course of mineral waters is usually beneficial. Boric acid or sodium biborate solution is the best local remedy.

Elschnig (*Wien. klin. Woch.*, Aug. 13, 1908) refers to two forms of chronic conjunctivitis, the first being conjunctivitis Meibomiana, which is produced by the hypersecretion of the Meibomian glands.

In the slight form of this variety, the transitory fold and bulbar conjunctiva do not become affected, and only the palpebral conjunctiva is diseased; the upper and lower lids become thickened, the lid margins red, the palpebral conjunctiva thick and velvety and diffusely reddened. There are often to be seen, through the thickened conjunctiva, Meibomian glands filled with yellow secretion; an intense amount of thin pus can be emptied by employing pressure. Sometimes diplobacilli are found in this secretion.

This variety of chronic conjunctivitis can be cured by a thorough evacuation of the Meibomian glands by expressing them every day or every week, according to the intensity of the affection, and the use of astringents.

It is mostly to be found in persons above 40 years of age.

The second variety of chronic conjunctivitis, which is not so well known, is produced either by an absolute or relative insufficiency of the lids. In slight closure of the lids the margins of the lids do not approximate completely. This is readily observed when the patient is asleep. In these cases, the bulbar conjunctiva near the lower corneal margin is dry, thickened, scaly and sometimes sclerotic. These eyes must be protected overnight with a bandage; a 2 to 4 per cent. boro-

lanolin ointment is to be applied every night to the lower conjunctival sac.—(C. P. S.)

Conjunctivitis, Chronic calcareous. In Bogota, Colombia, out of 500 cases of eye disease, systematic examination of the conjunctiva by Arbolda (*Anales de Oftalmol.,* Feb., 1913) showed in twenty an affection characterized by the presence of minute calcareous bodies in the palpebral conjunctiva. These bodies occurred at the lid margins, on the tarsus, and only rarely in the culs-de-sac. They were whitish-yellow in color. When numerous they produced the symptoms of foreign bodies in the conjunctiva. They were composed principally of calcium carbonate. Arbolda distinguishes this condition from so-called conjunctival lithiasis (in which the bodies do not contain calcium salts), and also from Leber's conjunctivitis petrificans (which is especially located in the cul-de-sac and attacks the bulbar conjunctiva). The only successful treatment proved to be surgical removal. This Arbolda did by curettement after cocainization. But relapses were the rule. See, also, **Conjunctivitis petrificans.**

Conjunctivitis, Coccidial. Sakaguci (*Nippon Gankakai, Zachi,* March, 1911) records a case of this rare disease in which some member of the family of the Coccidæ, or scale-insects (living in plants), had entered the sac and had set up a conjunctivitis.

Conjunctivitis, Croupous. That variety of conjunctivitis which is characterized by the formation of a more or less extensive membrane upon the surface of the conjunctiva of the lids. The intensity of the inflammatory process varies. In some cases the membrane is thin and gelatinous, and comes away in threads, while in others it is dense, thick, and yellowish-white, and comes away in large pieces, or entire. When removed it leaves a bleeding surface beneath. Here the conjunctival inflammation is probably of the same nature as the purulent form of conjunctivitis, but the exudation is of a higher organization. See **Conjunctivitis, Membranous.**

Conjunctivitis crouposa. (L.) Membranous conjunctivitis; Croupous conjunctivitis. See **Conjunctivitis Croupous.**

Conjunctivitis, Diphtheritic. See **Conjunctivitis, Membranous.**

Conjunctivitis, Diphtheritica. (L.) Diphtheritic conjunctivitis.

Conjunctivitis, Diplobacillary. See **Conjunctivitis, Morax-Axenfeld.**

Conjunctivitis eczematosa. (L.) Eczematous conjunctivitis.

Conjunctivitis, Eczematous. See **Conjunctivitis, Phlyctenular.**

Conjunctivitis, Endogenous. Metastatic conjunctivitis. Inflammation of the conjunctiva from toxins and other causes arising *within* the body, and not an infection of the usual type, from without. Among

these (discussed under their appropriate headings) are the gonorrheal, streptococcic and tubercular poisons.

Conjunctivitis entomotoxica. Kuroknsakame or Fu (scotmophora vermiculata) is an insect of the species pentatomidæ, which lives in Japan and does great harm to the rice plantations. If it comes in contact with the human eye, produces violent inflammation. Takashima (*Klin. Mon. f. Aug.*, 50, II, December, 1912, p. 685) reports four cases and his experiments with the juice of the insect on the eyes of rabbits, with the following résumé: The eye symptoms are edema of the conjunctiva and lids, intense lachrymation and mucopurulent secretion, sometimes subconjunctival hemorrhages and affections of the cornea. Its effect is similar to abrin, dionin, cantharidin, poison of the bee and ascarides, and blood of the eel. Watery or etheric solutions of the juice were ineffectual, and the search for formic acid and cantharidin in it was negative. The body of the insect has the same effect, as its gland most likely contains a gaseous substance which has a deleterious influence on the eye.

Conjunctivitis erysipelatosa. (L.) Erysipelatous conjunctivitis. See **Conjunctivitis, Acute catarrhal.**

Conjunctivitis exanthematica. (L.) Exanthematous conjunctivitis.

Conjunctivitis, Exanthematous, includes a variety of conjunctival affections due to such diseases as small-pox, measles, scarlatina, etc. The conjunctivitis associated with the exanthemata may be hyperemic, catarrhal, or purulent, or all three at different periods. A pustule of small-pox may show itself on the conjunctiva, but the most destructive action of this disease is on the cornea. The conjunctiva may also be inoculated with vaccine matter. Very commonly after convalescence from the exanthemata, and in measles particularly, there remains a chronic hyperemia or congestion of the conjunctiva, which is very persistent and obstinate to all manner of treatment. Conjunctivitis is very often a most prominent feature in *hay fever, rose cold* and *epidemic influenza,* and frequently demands special attention. See, also, **Conjunctivitis, Acute catarrhal.**

Conjunctivitis, Face-powder. This is a term applied by Nelson Miles Black (*Jour. Am. Med. Assoc'n,* April 18, 1914) to a form of conjunctival disease in patients, invariably women, who complain of "vision frequently being blurred, inability to use the eyes for any length of time for near vision, and severe itching of the lids which frequently is intolerable. The slightest rubbing of the lids produces quite marked bulbar hyperemia and only aggravates the itching. In severe cases the lids frequently appear quite edematous from the constant hard rubbing. There is a mucilaginous secretion in varying amounts, which

when being removed pulls out in long strings and is quite elastic. Microscopic examination of the secretion reveals great numbers of epithelial cells, in the midst of which or surrounding which are found masses of what appear to be pentagonal crystals, the majority having a central black spot which may be brought out more plainly by slight changes with the fine adjustment. In a few cases there are many fine amorphous crystals disseminated throughout the mass of epithelial cells, and pentagonal crystal-like bodies, but these are not constant. Micro-organisms are conspicuous by their absence."

Smears taken from these cases have been shown to a number of pathologists, bacteriologists and chemists and the symptoms described, but a satisfactory explanation has never been given. Many suggested that the "crystals" might be secreted by the lachrymal gland, others that they were artefacts. Slides prepared from secretion taken from the eyes of two sisters having the usual train of symptoms were examined by C. H. Bunting, who found that after trying various solvents, strong alkalies caused the crystals to swell and become spherical with a doubly contoured wall. When they swelled enough to rupture, iodin showed that they discharged soluble starch into the surrounding fluid proving that they were plant-cells, probably from some face-powder. They were not lycopodium.

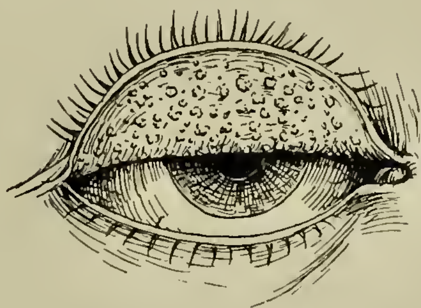
After examination of various face- and dusting-powders, Bunting reported that the irritating crystals probably came from rice-powder.

Seven other patients in whom the same symptoms and microscopic conditions were found all used the same make of face-powder.

In all probability when powder is applied to the face with a puff a portion of the fine dust is driven upward and lodges on the moist conjunctiva. The rice-flour in the presence of the tears becomes mucilaginous in character and is not washed from the cul-de-sac. The woody cells of the hard exterior of the rice-grain swell, and the angular corners produce the conjunctival irritation, which is aggravated by rubbing. Those who use a chamois-skin in applying the powder are less liable to cause the fine dust to arise, which probably accounts for the condition not being found in every person using face-powder.

The condition, according to Black, is quickly relieved by flushing the cul-de-sac with boric or normal salt solution and the use of an ointment made up of equal parts of lanolin and petrolatum, which seems to cause an agglutination of the cells and permit their being easily flushed out; 0.5 per cent. yellow oxid of mercury salve is usually prescribed. The irritation quickly subsides under a sedative collyrium.—(C. P. S.) See, also, **Conjunctivitis, Acute catarrhal.**

Conjunctivitis, Follicular. Simple granular lids. Granular conjunctivitis. Follicular ophthalmia. So named because of the enlargement of the adenoid tissue, which takes the form of small round or oval translucent bodies, which are seldom larger than a rapeseed and resemble follicles. They are more numerous in the lower than in the upper fornix, and they lift up the conjunctiva forming small elevations, often arranged in rows parallel with the folds of the membrane. They are reddish or yellowish in color, and the conjunctiva beneath them may be thickened but is soft and pliable. They are simply the enlarged or hypertrophied normal papillæ or follicles of the membrane. It frequently follows a purulent or muco-purulent conjunctivitis, and it is often impossible to fix the beginning of the disease. Among school-children examined by Stephenson in 1895, he found this condition present in seventy-five per cent. of them. Tra-



Follicular Conjunctivitis

choma never develops from simple granular conjunctivitis, and no matter how long the inflammatory process continues, there is no tendency to a destructive process, the conjunctiva being left intact. It has been a matter of considerable dispute whether or not there is any relationship between folliculosis and trachoma, but it is the general opinion of ophthalmic surgeons that they are clinically distinct diseases although histologically there is no line of demarcation between fresh follicles and fresh trachoma bodies. In differentiating the two diseases, there are certain marked differences characterizing each. Folliculosis is not contagious, when there is no discharge, while trachoma is usually contagious. Folliculosis is not associated with corneal complications, or with structural changes in the tarsal plate, and it never causes trichiasis, entropion or ectropion. Trachoma, on the other hand is often associated with pannus, corneal ulceration, trichiasis, entropion, or ectropion. Trachoma may occur at any age, while folliculosis is rarely seen after the twentieth year. Stephenson then describes the conjunctival appearances:

False, or follicular granulation.—Oval or roundish transparent bodies, the diameter of which, seldom or never exceeds 1 or 1.5 millimetres.* They often show a faint-yellowish hue, and are usually arranged in rows. Their tendency is usually to remain discrete: that is, separate from one another. They are always larger and better marked in the lower fornix.

True, or "sago-grain" granulation.—Round, opaque, ill-defined bodies, of grayish-white color, and extreme friability. They are firmly and deeply imbedded in the conjunctiva, their diameter frequently reaching 2 millimetres or more. Their tendency is to become confluent, thus forming areas of trachomatous material. They are always larger and more numerous in the upper fornix.

It must be borne in mind that in some instances folliculosis may be grafted on true trachoma, making a *mixed* form.

It has been frequently stated that follicular conjunctivitis is caused by unhygienic surroundings, or by vitiated air, but Stephenson has shown that it occurs as frequently among the children of the rich, and in the most favorable surroundings, as it does among the poor. It is often found among the children of farmers, who have no lack of fresh air and sunlight. The symptoms of the disease are those of a chronic congestion, or of catarrhal or purulent conjunctivitis, according as the one or the other process in the conjunctiva is more active. There is more or less discomfort about the eyes, and inability to use them, especially by artificial light. The lids feel heavy, and if there is considerable secretion the edges of the lids will be stuck together on waking in the morning, and crusts will form along the roots of the lashes.

Treatment must be directed towards reduction of the hypertrophied papillæ, and to combat the catarrhal condition if present. When the amount of secretion is but slight, the milder astringents are used: A ½ per cent. solution of nitrate of silver; or zinc sulphate, 2 gr. to the ounce, used as a collyrium twice a day is sometimes sufficient. If the discharge is more abundant the stronger irritating astringents will have a more pronounced effect. A smooth crystal of the sulphate of copper rubbed over the exposed surface of the everted conjunctiva causes a temporary hyperemia which tends to improve the nutrition of the parts and to stimulate the absorbents. This application can be repeated as often as every other day, but usually twice or even once a week will be sufficient. An ointment of the subacetate of lead, 1 per cent. applied to the everted conjunctiva once a day, followed by massage is recommended by Stephenson. *Brown ointment* used in the

same way is usually very effective. To obtain the best results this ointment should be prepared by making the ordinary dilute citrine ointment with unrefined or brown cod liver oil instead of with the usual excipient, and this again diluted with from 30 to 40 per cent. of refined cod liver oil. A small quantity of this salve should be placed in the lower cul-de-sac, and then distributed over the anterior surface of the eyeball by having the patient rotate the globe in various directions. The upper lid is then gently massaged with the finger from one to three minutes, the patient, meanwhile, turning the eyeball well downward. The lower lid should be treated in the same manner while the globe is rotated upwards. The surplus ointment (which is of a dark brown color), should not be washed off the lashes and lid edges for an hour or two after the rubbing because its local, mildly corrective action seems to be of value in these cases.

The general health of the patient should receive attention in all cases, and after the disappearance of the disease the condition of the refraction should be examined and any errors corrected.—(C. P. S.)

Conjunctivitis, Follicular, Bacteriology of. See **Bacteriology of the eye,** Vol. II of this *Encyclopedia*.

Conjunctivitis follicularis. (L.) Follicular conjunctivitis.

Conjunctivitis from cholera. Frequently during the period of reaction of cholera a sharp conjunctival hyperemia, which may degenerate into catarrhal conjunctivitis, has been observed. See **Conjunctivitis, Acute catarrhal.**

Conjunctivitis from dengue. During the course of this disease, various ocular symptoms occur. Conjunctivitis may be present and even advance into a suppurative keratitis.

Conjunctivitis from eel's blood. Two observers (Pöllot and Rallson, as reported in the *Berlin Ophthalmological Society,* June 22, 1911) noted the occurrence of acute conjunctivitis after contact with the blood of an eel. In two cases observed by Steindorff, in which the contamination of the conjunctiva occurred when the eel was being cut up, there was very severe reaction. In one of the cases this set in instantly, in the other after a lapse of a few minutes. After a few days all acute symptoms passed off, though in one of the cases there was for a time a fine corneal haze; in one, accommodative asthenopia remained for a considerable time. Steindorff experimented with cats, rabbits and guinea-pigs, endeavoring to produce reaction by introducing eel's blood, but without any result whatever. See **Eel's blood.**

Conjunctivitis from epidemic influenza. Conjunctivitis is often a most prominent feature in *influenza, hay-fever* and *rose cold*, and fre-

quently demands special attention. See **Conjunctivitis, Acute contagious.**

Conjunctivitis from hay fever. One of the most frequent accompaniments of hay-fever is an acute conjunctivitis. See **Conjunctivitis, Acute contagious.**

Conjunctivitis from rare microörganisms, such as: *Bacillus diphtheriae, bacillus coli communis, bacillus subtilis, bacillus pyocyaneus, bacillus mucosus capsulatus, micrococcus catarrhalis,* and the *meningococcus.* See the different forms of conjunctivitis as alphabetically arranged.

Conjunctivitis from rose cold. Conjunctivitis of a mild catarrhal type is a frequent accompaniment of rose cold. See **Conjunctivitis, Acute contagious.**

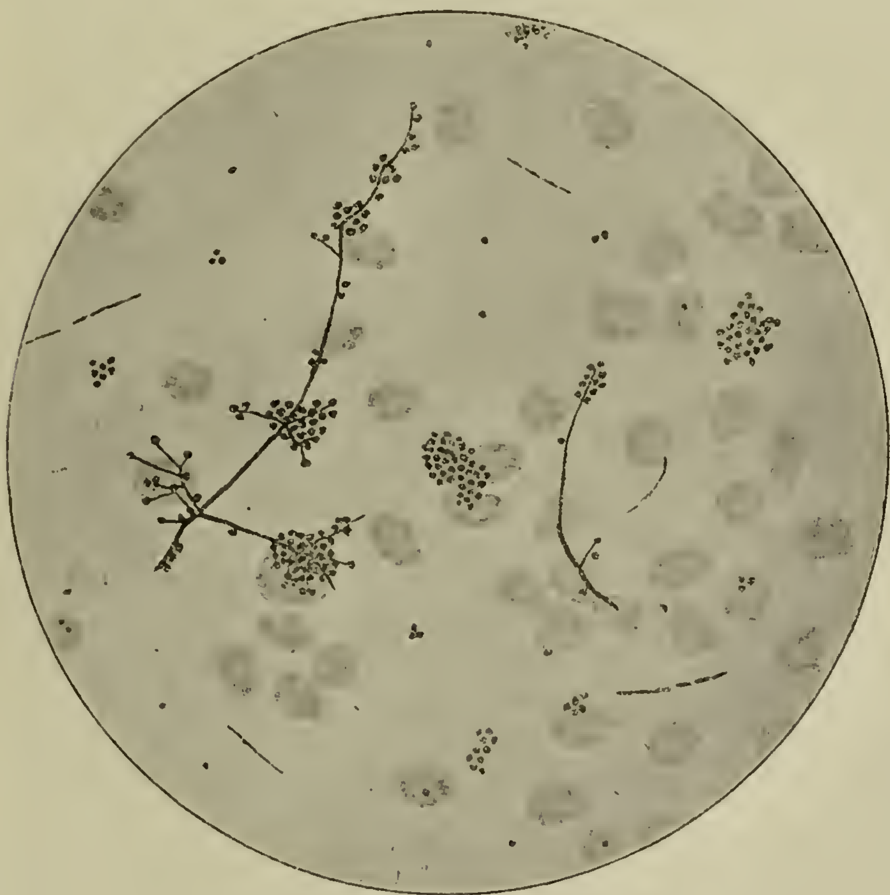
Conjunctivitis from snow-blindness (Conjunctivitis nivalis) follows a long tramp on the snow in the sunlight, more often on the mountains than on level ground. The disease cannot be said to be frequent, if one considers the large number of persons, both tourists and soldiers, who become blinded in this way. There occur all the signs of an acute inflammation of the conjunctiva. In addition to the influence of the reflected rays of the sun, which are chiefly responsible for the effect, there are also the heat rays to be considered; the more so since a similar, although not so severe, conjunctivitis follows a climb on calcareous mountains in midsummer, where the rocks emit much heat.

In order to avoid the trouble, protective glasses should be worn. The treatment requires keeping the patient in a subdued light; applications of cold water, boric acid solution, aqua plumbi, etc., two or three times a day. Each application should last fifteen minutes, with frequent change of the cloth. See, also, **Conjunctivitis, Traumatic.**

Conjunctivitis from the Nocardia dassonvillei. A report of this form of conjunctival infection—which must be exceedingly rare—is given by Liégard and Landrieu (*Bulletins et Mémoires de la Soc. Frs. d'Ophtal.,* 1912, p. 434). The case in point was that of an old lady who had a unilateral conjunctivitis that resisted all the usual forms of treatment for several weeks. Although the lids did not adhere in the morning yet there was a good deal of secretion at the inner canthus. Otherwise she had the picture of a chronic conjunctival catarrh with swelling of the caruncle and lid edges. A smear and a gelatine culture revealed the presence of numerous small cocci and several fine, long bacilli. Gram staining showed, also, filaments that closely resembled the mycelium of a fungus, some of them like chains of streptococci (see figure). After many cultural and animal experiments it was decided that the micrococci were identical with the streptothrix

dassonvillei, described and labeled by Brocq-Rousseu (*Thèse de Paris,* 1907).

Gasparini, in 1890, studied it under the name *streptothrix forsteri,* a fungus isolated by him from the air of inhabited houses, whose cultural characteristics are exactly the same as those of this micro-organism. It also had the peculiar odor developed by the Nocardia cultures. Since then we know that the Nocardia grows on grain, fruit, etc. It is very likely that in the case under discussion the organism developed



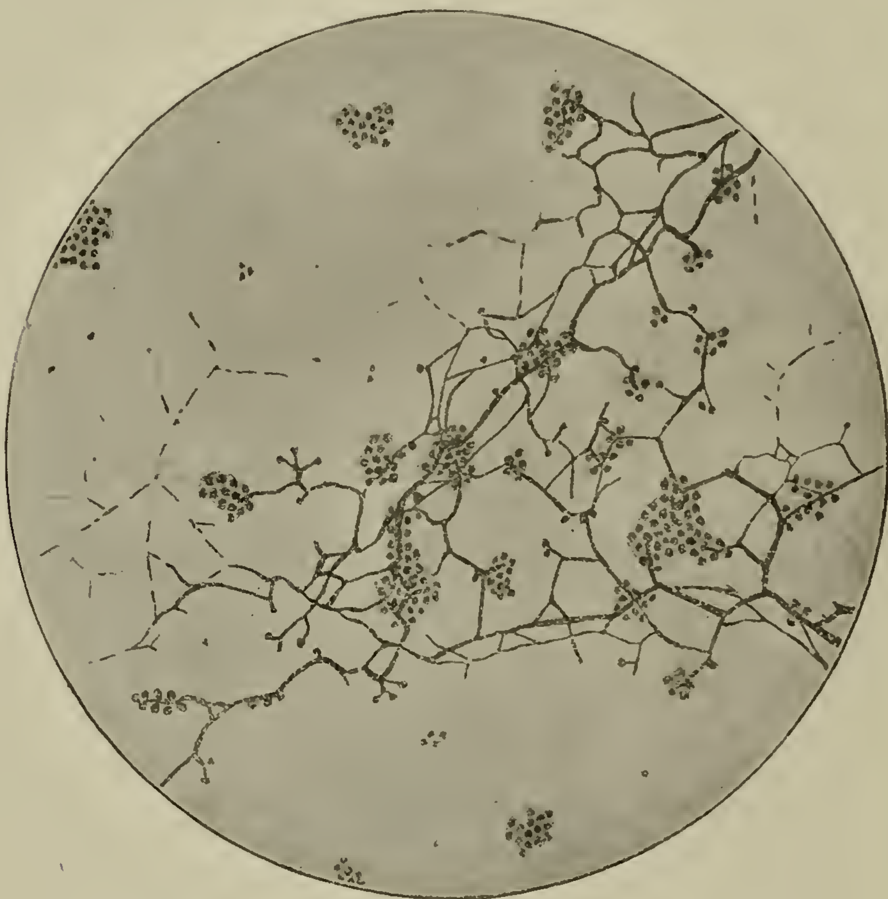
Conjunctival Smear of Nocardia dassonvillei.

from the face-powder which Liegard's patient was in the habit of using. The writers believe that certain obstinate subacute forms of conjunctivitis may occasionally be due to this fungus growth.

Conjunctivitis, Gonorrheal. OPHTHALMIA NEONATORUM. BLENNORRHEA NEONATORUM. OPHTHALMOBLENNORRHEA. See **Conjunctivitis, Purulent.**

Conjunctivitis gonorrheica. (L). Gonorrheal conjunctivitis. See **Conjunctivitis, Purulent.**

Conjunctivitis, Granular. Conjunctivitis granulosa, or trachomatosa. Egyptian ophthalmia. Trachoma. Military ophthalmia. Granular lids. Although this most important subject will be further discussed under the caption **Trachoma**, it may be said here that we generally understand by Trachoma the popular term "granular lids," an inflammation characterized by the presence of trachoma bodies or granulations which are particularly abundant in the conjunctiva of the upper lid and fornix, and marked in the later stages of the disease



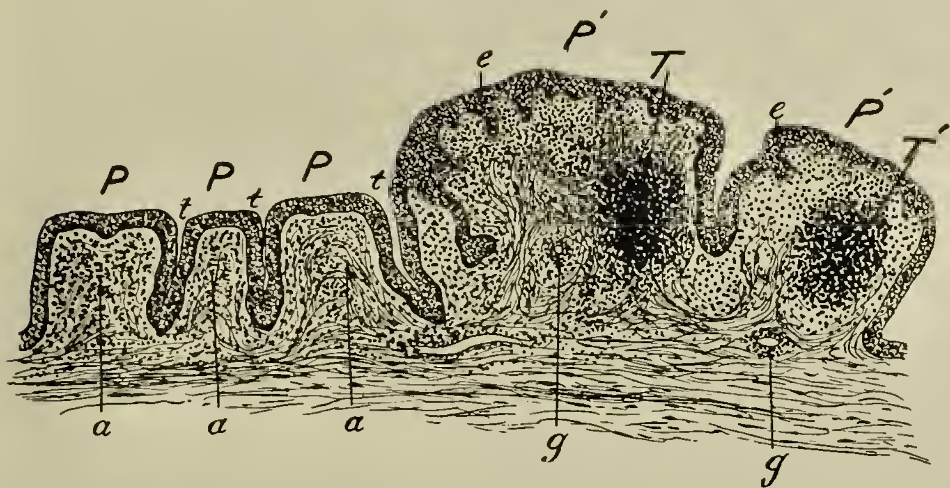
Nocardi Conjunctivitis. Culture on Gelatine (15 days).

by cicatricial changes. The grayish or pinkish-red bodies, usually about the size of a pin-head, may also exist in the lower lid and in the bulbar conjunctiva. The cornea may also show the presence of trachomatous tissue. The disease almost always attacks both eyes. The cause of the disease is unknown. Different investigators have from time to time reported the discovery of the etiological factor, and while there has been a notable advance in our knowledge of conjunctival diseases during the last few years the real cause of trachoma still remains undiscovered. For a full description of the bacteriology of

trachoma, the reader is referred to page 834, Vol. II of this *Encyclopedia.*

The disease is spread by the transference of secretion from a trachomatous eye, and the virulence of the process depends upon the quantity and quality of the discharge. When this discharge is profuse and yellowish in color, the degree of contagiousness is proportionately great. A trachoma which is kept in check by proper treatment is but slightly contagious.

Since the medium of infection is usually the finger, or some article used in making the toilet, such as handkerchief, towel, sponges, etc., a



Cross Section Through the Trachomatous Conjunctiva of the Upper Lid. (Fuchs.)

Both small papillæ, *P,P,P,* and large ones, *P, P,* are found. The depressions, *t,t,t,* lying between the small papillæ are coated with epithelium and look like the tubules of glands. The large papillæ contain trachoma granules, *T, T,* which are not sharply limited, and do not possess a capsule. The epithelium of the conjunctiva is in many places thickened, *e,e.* The mucous coat is in a condition of cellular infiltration, *a,* which is especially marked in the vicinity of the blood-vessels, *g,g.*

particularly easy opportunity for this to occur is afforded where a large number of people have their sleeping apartments in common, and so, too, make common use of toilet articles. Hence, trachoma spreads most extensively in work-houses, barracks, penal institutions, boarding schools, orphan asylums, etc. Outside of such institutions moreover, trachoma attacks mainly poor people living in crowded and unhygienic surroundings, who give little attention even to ordinary cleanliness.

Race, also, seems to be an etiological factor. In some countries the Jews are special sufferers from trachoma. The disease is most frequent in Arabia and in Egypt, which is regarded as its proper home (*ophthalmia Ægyptiaca).* In Europe it is much more wide-spread in the East

than in the West. Elevated lands (Switzerland, Tyrol) are almost entirely free from it, while it is very frequently found in the low lands (Belgium, Holland, Hungary, and the whole region of the lower Danube). In our own country it is rather common in Eastern cities, especially among the foreign population, especially Russian and Polish Jews, and immigrants from eastern Europe generally, and among the Irish and Italian. It occurs frequently too, among the Chinese and Japanese. Among native Americans, particularly in some parts of the middle west (Illinois, Kentucky, West Virginia) it is common, and often in a severe form. It is prevalent among the Indians, while negroes, at least in this country and in Cuba, are almost exempt. It is stated by Ziem that the prevalence of the disease has kept pace with the destruction of forests and the consequent production of dust and sand storms. Kuhnt believes that nasal disease is an etiological factor.

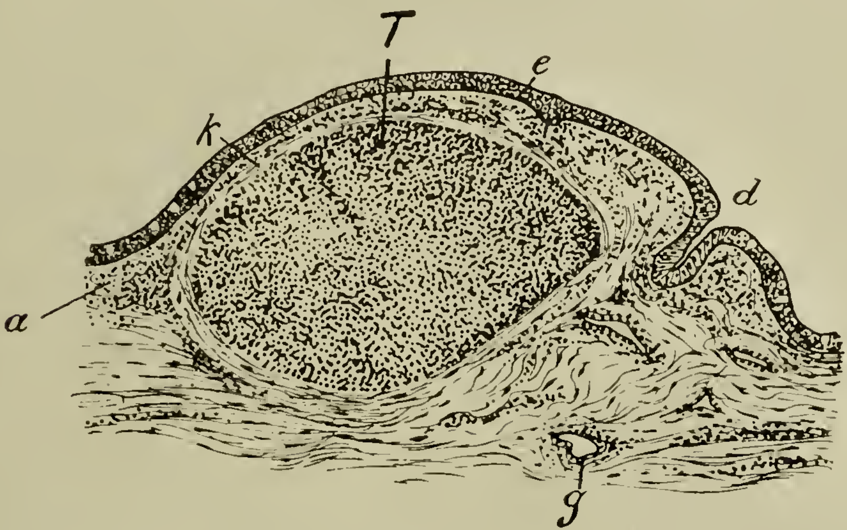
When, in 1798, Napoleon I with an army of thirty-two thousand men landed in Egypt, a large number of these soldiers were very soon attacked with a violent ophthalmia, and when they returned it was supposed that this disease (ophthalmia militaris) was for the first time introduced into Europe. It has since been shown by historical researches that the disease had been endemic in Europe since antiquity. It is mentioned in the Ebers papyrus and in a pseudo-Hippocratic manuscript. Celsus gives a good description of the roughness of the lids and the purulent discharge it occasions.

Of the early records of trachoma epidemics, Fuchs states that at about the time of the Napoleonic wars, and in many places by reason of them the disease became frightfully prevalent. In the English army during the year 1818 there were more than 5,000 blind from trachoma. In the Prussian army, from 1813 to 1817, between twenty and thirty thousand men were attacked by it; in the Russian army from 1816 to 1839, 76,811 men were subjects of the disease. In Belgium in 1840 one out of every five soldiers was affected with trachoma. Jüngken, at that time a celebrated ophthalmologist in Berlin, recommended to the government that these trachomatous soldiers be dismissed to their homes. Because of this fatal measure trachoma soon became diffused in Belgium to an extent that has been observed in no other European state.

At the present time we do not see epidemics of the disease, but it exists in many countries as an endemic affection. Its prevalence, too, has diminished. In 1888 the Prussian army had but ten trachoma patients for every thousand soldiers. In the Orient, however, there is a very different state of affairs. Thus in Egypt, even at the present

time, it is scarcely possible to find a native who has a normal conjunctiva, and innumerable people there are blind from this cause. —(C. P. S.)

For the discussion of this disease in its anatomical and clinical aspects, see **Trachoma**.



Trachomatous Granulation from the Fold of Transition. (Fuchs.)

Conjunctivitis granulosa. (L.) Granular conjunctivitis.

Conjunctivitis gummatosa. (L.) Gummatous conjunctivitis. See **Conjunctiva, Syphilis of the.**

Conjunctivitis gummosa. (L.) Gummatous conjunctivitis.

Conjunctivitis, Hop picker's. Women and children employed in picking hops are, according to Adams (*Brit. Med. Journal,* May, 1893), subject to a form of acute conjunctivitis, sometimes accompanied by keratitis and hypopyon, due to the hairs of the bracts and katkins of the plant.

Conjunctivitis hypertrophica. (L.) Hypertrophic conjunctivitis.

Conjunctivitis ichthyotoxica. See **Conjunctivitis, Toxic.**

Conjunctivitis, Inclusion. Inclusion blennorrhea. Lindner (Graefe's *Arch. f. Ophth.,* lxxiv, I, 1.) has studied the virus of inclusion blennorrhea and trachoma, which he successfully inoculated into pavians. The results of the inoculation were controlled microscopically and with regard to their biologic qualities, viz., resistance to external influences, exsiccation, longer moist preservation, temperature, etc., and as to the possibility of filtration. He also investigated the total or partial immunity after a single infection and the relations between trachoma and inclusion blennorrhea. He found that the virus of inclusion blennorrhea of the conjunctiva of the newborn or of the genitals of adults,

if directly inoculated into the conjunctiva, almost always produces inclusion conjunctivitis. The disease may start acutely after from 2 to 6 days or subacutely after from 7 to 11 days. The microscopic proof of inclusions and free initial bodies is possible only for a few days, in acute cases abundantly, in chronic more scantily, although the disease continues. The reinfection experiments showed a certain immunity after a single infection. The virus of inclusion blennorrhea is very unstable.

The conjunctivitis produced by inclusion blennorrhea virus from the genitals of adults resembles most closely those lesions created by trachoma after longer incubation, and shows scanty or no microscopic findings. Lindner concludes that there is no absolute argument against the etiologic identity of trachoma and inclusion blennorrhea.

The histologic description of the conjunctiva of the pavian after infection with trachoma virus or inclusion blennorrhea shows that inclusion blennorrhea and trachoma produce analogous changes in the conjunctiva. During period of observation (2 years) cicatrization has not been observed. The transmission of trachoma virus to the genital mucous membrane, as the last link in the chain of proof by experiments in animals, is still to be furnished. Three such experiments were negative.

The investigations here reported together with those published by Botteri strengthen our views concerning the infectiousness of inclusion diseases. The virus (trachoma or inclusion blennorrhea) is more sensitive to external influences than the germs of other ocular diseases. This fact explains why epidemics or endemics do not break out among populations with highly developed hygiene and why among such populations an infection of adults occurs so rarely. Although some questions are still unsolved Lindner believes that trachoma and inclusion blennorrhea are etiologically identical.—(C. P. S.) See, also, **Trachoma.**

Conjunctivitis in dysentery. A form of conjunctivitis sometimes occurs during a course of dysentery, produced by the passage of germs proceeding from the large intestine (at times suppurating or sphacelated) through the circulatory channels of the organism. See, also, **Conjunctivitis, Toxic.**

Conjunctivitis in influenza. From the commencement of an attack of influenza, there is observed a sharp conjunctivitis, whose origin may be traced to an intense catarrhal affection of the nasal mucous membrane. See, also, **Conjunctivitis, Toxic.**

Conjunctivitis in malaria. Certain observers have described the oc-

currence of conjunctivitis as one of the manifestations of malaria. It yields readily to quinine. See, also, **Conjunctivitis, Toxic.**

Conjunctivitis jequiritica. (L.) JEQUIRITY OPHTHALMIA. See **Conjunctivitis, Toxic.**

Conjunctivitis, Lachrymal. This term is applied to those cases of conjunctival inflammation which are produced by the irritation of the discharge from an inflamed lachrymal sac. Various pathogenic germs are found in dacryocystitis, one of the most important being the streptococcus pyogenes. From contact with the irritating discharge, the caruncle and plica semilunaris become inflamed. The cause may be easily determined if the surgeon thinks to investigate the condition of the lachrymal apparatus. Often this examination is overlooked and the disease is classed as an intractable chronic catarrhal conjunctivitis. The prognosis will depend on that of the lachrymal disease. The cure of dacryocystitis will cause immediate improvement in the condition of the conjunctiva. If a corneal ulcer has been infected with the lachrymal discharge, the prognosis may be serious, such cases occasionally leading to deep ulceration of the cornea, with perforation and loss of the eye (Ball). See, also, **Conjunctivitis, Acute catarrhal.**

Conjunctivitis, Larval. This form of conjunctivitis is caused by the eggs of flies. The eggs become deposited in the conjunctival sac, and after hatching, the larvæ may produce a decided irritation with swelling of the conjunctiva and the production of a muco-purulent secretion. Children are most apt to be affected. See, also, **Conjunctivitis in general.**

Conjunctivitis, Lithiasis. Irritation of the conjunctiva due to deposition of calcareous matter in the tissue of the palpebral conjunctiva. See **Conjunctiva, Lithiasis of the.**

Conjunctivitis, Lymphatic. See **Conjunctivitis, Phlyctenular.**

Conjunctivitis lymphatica. Lymphatic conjunctivitis.

Conjunctivitis medicamentosa. (L.) Toxic conjunctivitis.

Conjunctivitis membranacea. (L.) CONJUNCTIVITIS MEMBRANOSA. CROUPOUS CONJUNCTIVITIS. MEMBRANOUS CONJUNCTIVITIS. See **Conjunctivitis, Membranous.**

Conjunctivitis membranosa. (L.) Croupous conjunctivitis.

Conjunctivitis, Membranous. CROUPOUS CONJUNCTIVITIS. DIPHTHERITIC CONJUNCTIVITIS. PSEUDO-MEMBRANOUS CONJUNCTIVITIS. PLASTIC CONJUNCTIVITIS. This is a form of conjunctivitis in which the formation of what appears to be a distinct membrane is the important feature so far as it indicates an exudation form of inflammation, and, almost certainly, a specific cause. It has been thought possible to divide this

so-called membranous conjunctivitis into two distinct forms,—the croupous and the diphtheritic. The relation of croupous to diphtheritic conjunctivitis has been the cause of much controversy. While there are indeed ample grounds for making two forms of membranous conjunctivitis, so far as regards their clinical aspects, there seems to be some difficulty in classifying these categorically as croupous and diphtheritic on the basis of either etiology or bacteriology. It would seem that the presence or absence of the Klebs-Löeffler bacillus cannot be relied upon, certainly in the differential diagnosis of diphtheria, for, as the investigations of Tarze, Uhthoff, Sourdille, Morax, and others have shown, it has been found in cases which clinically fall in the croupous group; and its presence has not been demonstrated in severe cases which have all the characteristics of diphtheria, as has been shown by Weeks, Standish, and Burnett. The only microbe found in these cases was a streptococcus. At the present time the views of Coppez, who finds that the symptoms, both local and general, gradually merge in the two affections, are accepted. Some cases diagnosed as croupous conjunctivitis have been followed by fatal systemic infection, and others by post-diphtheritic paralysis. Gossetti and Iona found the diphtheria bacillus present in six out of twenty-nine cases of croupous conjunctivitis.

For clinical purposes, however, it is still best to retain the distinction and consider each form separately, though it seems probable that in the near future we shall be able to classify them definitely according to the bacteriological findings.

During a period of five years, Meyerhof (*Revue Générale d'Ophtalmologie*, March, 1909) examined bacteriologically over 1,500 cases of acute ophthalmia in Egypt. Among this number were 110 cases of conjunctivitis in which the formation of a membrane was noted.

Meyerhof divides the 110 cases into three groups according to the severity of the attack, without reference to the causative agent. 1. Mild or catarrhal form, characterized by the absence of severe inflammatory signs and by the ease with which the pellicle can be detached. 2. Severe, or purulent form, in which there is edema of lids, rise of temperature, and a very adherent pellicle on the conjunctiva. 3. Diphtherial form, always severe and usually complicated by corneal lesions.

It is necessary to note that the author employs the term diphtheria in a purely clinical sense. In his 110 cases he tabulates 11 cases as diphtherial, but in only 3 of these was the bacillus of Löeffler present. Moreover, in two cases which he places in the second (purulent) group, Löeffler's bacillus was the active micro-organism.

The majority of the 110 cases belonged to the indigent population;

52 males, 58 females. There were only 12 adults; and of the 98 children the greater number were under five years of age. In most instances both eyes were simultaneously attacked. Occasionally the disease in one eye assumed a membranous character, while in the other it was catarrhal or purulent.

A very marked seasonal variation was noted. During the winter months, from December to the end of March, the number of cases was very small. From April to June the number increased rapidly, fell again in July and August, and rose in October to the same height as in June.

Bacteriological examination of the 110 cases showed the presence in the secretion and in the false membrane of the following microbes:

Koch-Weeks' bacillus	61 cases.
Neisser's gonococcus	32 "
Streptococcus pyogenes	7 "
Löeffler bacillus	5 "

In 5 cases, of which 2 were "diphtheritic," no micro-organisms were discovered.

In 15 cases more than one of the above microbes were found in the membranous exudation, or the co-existence of the staphylococcus aureus or the pneumococcus was revealed; but in no instance was either of the two last named cocci found alone, and in no case was the diplo-bacillus of Morax, or the influenza bacillus discovered.

The relation of the three clinical forms of these diseases to the four varieties of micro-organisms mentioned above is best shown in tabular form:—

	Type of disease.			
	Catarrhal.	Purulent.	Diphth.	Total.
Koch-Weeks'	6	53	2	61
Gonococcus	2	28	2	32
Streptococcus	—	5	2	7
Bacillus of Löeffler	—	2	3	5
No microbes	2	1	2	5
	10	89	11	110

It would appear from Meyerhof's results that each of the three described forms of membranous conjunctivitis, and notably the diphtherial form, may be produced by any one of the four micro-organisms in the above list. He holds that the difference between the variety he terms diphtherial, and the other forms is, clinically and anatomically, essentially one of degree of severity and liability to dangerous complications, such as corneal ulceration and sloughing.

In 40 of the cases corneal lesions varying from superficial infiltrations to total necrosis were present when the patients came under observation; in 3 others the cornea became affected during treatment.

In a large percentage of the cases the membranous conjunctivitis occurred in patients the subjects of trachoma; this fact may be of importance in relation to the character of the attacks, especially in instances of a clinically diphtheritic type of disease, excited by microbes other than Löeffler's bacillus.

In reference to the treatment of membranous conjunctivitis, it is noteworthy that, apart from serum treatment in diphtheria Meyerhof relies chiefly on applications of silver, using a 2 per cent. solution of the nitrate, as well as the more modern preparations.

The dread of silver salts in membranous forms of conjunctivitis is, in his experience, baseless.

Attias, of Naples, reports (*Arch. di Ottal.*, May, 1913) a case of pseudo-membranous conjunctivitis, caused, he believes, by the bacillus subtilis. This bacillus was first brought into relation to ophthalmology in papers by Poplawska and Haab, who in 1891 demonstrated its presence in the vitreous in several cases of injury followed by panophthalmitis. In 1905 Zur Nedden proved this bacillus to have been the cause of hypopyon ulcer in two cases, and Cramer did the same in a case of abscess of the orbit. It is thus seen that isolated examples of various inflammatory affections of the eye may be due to this organism, which has also been found by Fava on the lid-margins in a few healthy individuals. Attias claims that this bacillus was the cause of the pseudo-membranous conjunctivitis in an infant twenty days old, brought by the mother, who had observed the eyes to be reddened and discharging, even from a few days after the birth. The lids, especially the upper, were slightly tumefied and engorged. The conjunctiva of the upper lid was still more injected and was covered by a pseudo-membrane of a pale-yellowish color, which was fairly adherent to the underlying tissue, and from which it could not be removed without some hemorrhage: there was a very moderate amount of discharge. The cornea remained transparent and the general condition of the infant was perfectly satisfactory.

As a precaution, however, injection of anti-diphtheritic serum was advised, in consequence of the membranous deposit on the lids, but the mother declined to allow this to be done, and local treatment alone was carried on, chiefly instillation of nitrate of silver and dusting in of iodoform powder. Under this treatment the condition improved quickly.

It does not seem necessary in this place to recount the reactions of

the organism and the tests applied to enable Attias to come to the emphatic conclusion that he had to do with a case of bacillus subtilis. Suffice it to say that the proof seems complete that in this instance a pseudo-membranous conjunctivitis simulating ophthalmia neonatorum had arisen from infection with this organism, a rare if not actually a unique, occurrence.

Croupous conjunctivitis presents itself as a mild or as a severe type, the onset being much like that of purulent conjunctivitis. There are pain, redness, and swelling of the lids, which, however, are not tense and hard, as in diphtheritic conjunctivitis, and in the beginning at least can be easily everted. The characteristic feature is the formation of a white or grayish membrane on the surface of the conjunctiva, which may cover the whole surface or appear only in patches, and is usually confined to the retrotarsal folds and the palpebral surface of the conjunctiva, the bulbar-conjunctiva seldom participating. This membrane can be wiped off, though sometimes only with considerable difficulty, revealing usually a raw and hemorrhagic surface underneath: a diagnostic point which serves to distinguish it from the diphtheritic form. This false membrane begins to cast itself off in a few days or perhaps not for about two weeks, when the stage of purulency sets in. There are then the symptoms and appearances characteristic of purulent conjunctivitis, which seems to be the manner of resolution of the disease. Occasionally the membrane comes away entire, but usually it is detached in patches, revealing a thickened and red conjunctiva beneath, which secretes pus. It sometimes happens that there is a re-formation of the membrane, and with it a return of the symptoms of hyperemic irritation. There is not usually any systemic disturbance, except a slight elevation in temperature. The cornea is seldom involved. The discharge is contagious and the same precautions should be used to avoid infection in the other eye, if only one is affected, and of the eyes of attendants, as are observed in treating purulent conjunctivitis.

The severe type of the disease, caused by streptococcic infection, shows great swelling of the lids, considerable discharge, and rapid destruction of the cornea, due to the spreading of the exudation upon the bulbar conjunctiva.

To differentiate this disease from diphtheritic conjunctivitis it is to be borne in mind that in the diphtheritic condition the exudation instead of being limited to the surface, involves the deeper layers of the conjunctiva; the bulbar portion of this membrane is involved, and corneal ulceration is frequent. In gonorrheal conjunctivitis the discharge is much more purulent than in the croupous form. Croupous

conjunctivitis is never found in the newborn. The diagnosis cannot always be made, however, by the clinical signs; dependence must be placed upon the bacteriological findings.

In the treatment of croupous conjunctivitis irritants and strong astringents must be avoided during the hyperemic stage. The eye should be kept thoroughly clean with mild antiseptics, and be protected by a bandage or a Buller shield. The local application of iced compresses, or, if the patient is feeble, of hot applications will be beneficial and efficient in hastening the casting off of the membrane. As soon as the stage of hyperemia has passed and the catarrhal symptoms have become established, then is the time to begin the use of nitrate of silver. Weak solutions should be used in the beginning, two or three grains to the ounce of water, and, if necessary, increasing the strength with the increase of the degree of purulency. If the cornea is involved, a bacteriological examination should be made. If the Klebs-Löeffler bacillus is found, diphtheria anti-toxin should be used.

The use of formalin has been suggested, and aristol is recommended as a local application where the cornea is involved.

Diphtheritic conjunctivitis. This is an extremely serious disease which occurs rather infrequently in the United States and in England, but is common in Germany and in some other Continental countries. Galezowski saw seven cases in one hundred and fifty thousand patients.

The clinical features of this disease are not only more intense in their manifestations than those of the croupous form, but have, in addition, many distinct characters of their own. The disease is divided clinically into three stages: those of infiltration, suppuration, and cicatrization. In the first stage, which lasts from six to ten days, the symptoms are similar to those attending purulent ophthalmia; the attending pain is, however, much more severe in the diphtheritic form. The lids are not only swollen and painful, but hard, feeling, sometimes, like board, and it is not possible to evert them. The conjunctiva of the lids is thickened and infiltrated with a plastic material, which may in severe cases extend to the bulbar conjunctiva. If this is stripped off the surface beneath is of a gray or buff color, the same as that of the layer of the infiltrate, and not red and bleeding, as in croupous conjunctivitis. Ecchymoses are quite commonly seen in the substance of the conjunctiva, which is not already infiltrated. There is danger at any time during this period of corneal necrosis from pressure on the vessels by the exudate, and this destructive process may advance so rapidly that the eye may be destroyed in twenty-four hours. The discharge is at first watery and flocculent resembling that of a beginning purulent inflammation. The next stage is marked by an amelioration of the

acute symptoms, a diminution in the hardness of the lids, and a change in the discharge to a more purulent character. The membrane begins to disappear by absorption, and is not cast off in patches, as in the croupous form. The conjunctiva begins to look reddish, raw, and succulent, and it is from this that the purulent secretion now comes. In severe cases, however, the patches slough out, leaving defects in the conjunctival substance which must heal with cicatrization. This constitutes the third stage, in which the conjunctiva is left atrophic and shrunken, with frequently great deformity of the lids. Trichiasis, entropion, symblepharon, and even exophthalmos may be produced. Involvement of the cornea, which is a frequent complication, assumes the form either of local ulceration or of diffuse infiltration. The advent of corneal involvement causes great pain.

It is no uncommon thing for relapses to occur, and this should always be guarded against as far as possible by careful attention to the local and general conditions.

In every marked case of diphtheritic conjunctivitis there is always more or less systemic disturbance; the depression of the vital forces is sometimes as profound as in the exaggerated forms of faucial diphtheria. There exist frequently a concomitant or subsequent conjunctival, faucial, and nasal diphtheria.

The discharge is contagious and the same precautions as to infection must be observed as are applicable to purulent conjunctivitis. It attacks by preference the young, though adults are by no means exempt, and it seems probable that the contagion can be conveyed by the air, and that its direct transference is not necessary for infection. Generally both eyes are involved.

As the sole etiological factor is the Klebs-Löeffler bacillus, an absolute diagnosis is impossible without a bacteriological examination. Coppez states that there is a group of bacteria: the xerosis bacillus, the pseudo-diphtheria bacillus of Hoffmann, and the bacterium septatum of Gelpke, which can be distinguished from the true diphtheria bacillus only by culture or by inoculation experiments. To make certain of the diagnosis of ocular diphtheria, he advises examination of cover-glass preparations, cultures on serum-agar, and the use of the Ernest-Neisser double coloration. Owing to the general presence of the xerosis bacillus in the conjunctiva, the making of a microscopic examination of the discharge is less valuable here than in faucial diphtheria.

In the treatment of diphtheritic conjunctivitis general sustaining, and even stimulating measures, are called for if the vital depression is at all marked. As soon as the positive diagnosis of diphtheritic con-

junctivitis has been made, an injection of antitoxin must be given. The earlier this is done, the less will be the danger of corneal sloughing. The injection should be repeated at the end of twenty-four hours. Improvement should be noticeable at the end of a few hours. Locally, cleanliness, with mild antiseptic or aseptic solutions and cocaine, is indicated, but in carrying out these measures we are very much hampered by the fact that the lids are so hard and unyielding as to make eversion and sometimes even separation impossible, and it should not be attempted in any forcible manner, on account of the intense pain it produces. The local application of hot water should be employed more frequently and for a longer time, than in the croupous form of the disease, as it alleviates the pain and tends to hasten the process of resolution. The application of cold, especially if continuous, would be likely to diminish still further the vitality of the parts, already much impaired. It is not advisable, unless the indications urgently demand it, to make a canthotomy for the relief of pressure, on account of the danger of opening up a new avenue of infection for the diphtheritic inflammation, and thus adding to the complications of the disease. When the stage of purulency has arrived, nitrate of silver is the remedy, but it must be used cautiously in the beginning, as the application of strong solutions has been followed by an exacerbation of the symptoms and a reformation of the membrane. Formalin, in solutions varying in strength from 1 to 2,000 to 1 to 500, according to the degree of purulency, has been recommended. Many topical remedies have from time to time been suggested and tried, to assist in the resolution of the exudation, such as citric acid, powdered quinine sulphate, etc., but none of them have come to anything like general acceptance in the therapeutics of the disease. The internal administration of mercury has been recommended by good authorities: five to ten centigrammes of calomel, given every two hours until visible effects of bringing about absorption of the exudation are manifest. This may be assisted by inunction of mercurial ointment.

If the cornea becomes ulcerated, atropine should be used in connection with the hot applications. Cauterization of the ulcers should not usually be attempted in the first stages, since they are usually due to lowered vitality and not altogether to microbic infection. Later, however, when resolution is setting in and vitality has returned, cauterization with the actual cautery or with formalin 1 to 60 is useful.

During the stage of cicatrization care should be taken to prevent adhesion between the lids and the ball, which is likely to take place when the two raw surfaces are brought together. The lids should be moved frequently over the ball, and vaselin used freely as a pro-

tection to the raw surfaces. It may be necessary to introduce a bit of thin charpie between them to keep the raw surfaces apart. The sound eye should be protected by a Buller shield.—(C. P. S.)

Conjunctivitis, Mercuric. See **Conjunctivitis, Toxic.**

Conjunctivitis, Metastatic. Endogenous conjunctivitis. Inflammation of the conjunctiva from toxins and other causes arising within the body, and not an infection of the usual type, from without, is not uncommon. In other words, one has to deal with a metastatic process. Among these (discussed under their appropriate headings) are the gonorrheal, streptococcic and tubercular poisons.

Conjunctivitis, Metastatic, Bacteriology of. See **Bacteriology of the eye.**

Conjunctivitis militaris. (L.) See **Trachoma.**

Conjunctivitis, Morax-Axenfeld. Morax-Axenfeld conjunctivitis presents in many instances a characteristic clinical picture. The subjective symptoms are, as a rule, mild, but these patients sometimes complain of epiphora, pain in the eyes, and of headache, which is worse at night. McKee noticed that a great many cases were among patients not easily disturbed by pain, so that he has come to believe the subjective symptoms are sometimes quite severe. According to Peters headache sometimes accompanies this infection and ceases when the conjunctivitis is relieved. While seeing a large number of these cases McKee has been struck with the frequency of the complaints of headache and other symptoms of asthenopia. This was specially noted in those cases of mild infection with but slight objective signs of conjunctivitis, but where the examination of the secretion from the inner canthus showed numerous diplo-bacilli.

Headache, which is more severe following close work, and in the late afternoon and evening, naturally leads us to seek some error of refraction as the cause. In a number of these cases we find no refractive error to account for the symptoms.

H. M., aged 24, who does office work, complained of headaches which were more severe in the late afternoon and evening. His refraction, examined under cycloplegia, was found to be normal. There was no muscular error and no changes in the fundi. Examination revealed a mild conjunctivitis and diplo-bacilli were found in numbers. Two weeks' treatment with the sulphate of zinc gave him complete relief from symptoms.

This case is quoted to illustrate a series of cases observed in adults and children. The subjective symptoms in each case pointed to an error of refraction but were due to a diplo-bacillary infection. At any rate the cure of the conjunctivitis relieved the symptoms entirely.

A typical case of Morax-Axenfeld conjunctivitis would present the following appearance: Beginning as a mild catarrhal conjunctivitis in one eye, both eyes soon become involved. The conjunctivitis increases in severity and in twenty-four to forty-eight hours there will be seen marked reddening of the lids, especially at the outer and inner canthi, some maceration of the skin and in the conjunctival sac a varied amount of watery discharge which gives the reddened lids a moist appearance. The blepharitis, with the reddening at the outer and inner canthi, makes the picture a marked one. The palpebral conjunctiva is more involved than the bulbar. It is generally only a "palpebral conjunctivitis."

Morax-Axenfeld conjunctivitis may be seen in any of the following forms: 1. A mild catarrhal conjunctivitis where the patient complains of headache, pain in the eyes, especially when reading at night. 2. A form of catarrhal conjunctivitis with some slight reddening at the outer and inner canthi (angular conjunctivitis). 3. A catarrhal conjunctivitis with accompanying blepharitis (blepharo-conjunctivitis.) 4. Acute purulent conjunctivitis.

In many cases the form of conjunctival infection shows the characteristic clinical picture of a mild catarrhal conjunctivitis with reddening at the outer and inner canthi, and in these cases a temporary diagnosis may be made from the clinical signs, but it is to be remembered that many cases showing a like clinical picture will present themselves where the etiologic factor is a very different one. No disease of the conjunctiva presents at times such a typical clinical picture as does this form, but at other times the clinical picture will give one no indication that the infection is diplo-bacillary.—(S. H. M.)

Sava-Coin (*Annales d'Oculistique*. August, 1911.) describes an epidemic of conjunctivitis in the civil and military population of Vaslui, Roumania. He was asked to institute prophylactic measures to arrest the epidemic, and also to discover the cause and origin of the disease. In the barracks of the 25th Regiment of Infantry he found 47 soldiers isolated; amongst the pupils of a primary school of boys 12 cases, and in the civil population 23 cases of conjunctivitis. As the first cases of conjunctivitis appeared after the soldiers had taken a bath in the town, he examined this place and found two boys bathing who were suffering from conjunctivitis, and in whom the bacteriological diagnosis confirmed the clinical supposition. Transmission seems to have been direct, for in the barracks several soldiers sleeping in neighboring beds contracted the disease at the same time, and the great majority of cases belonged to the same company. The

disease varied considerably in virulence, sometimes appearing as an acute or even blennorrhagic conjunctivitis, whilst in other cases the patients showed only a slight injection of the conjunctiva with a small amount of secretion. In no case was the cornea or iris affected. Out of 47 smears made from the soldiers the diplo-bacillus of Morax was found in 42, and in 18 of the smears, besides diplo-bacilli, Gram-positive cocci were found. Amongst the civil population the diplo-bacillus was always found, with occasionally a Gram-positive coccus. Cultures were only taken in 10 cases, in 3 of which the diplo-bacillus, and in all of them a variety of staphylococcus pyogenes, grew.

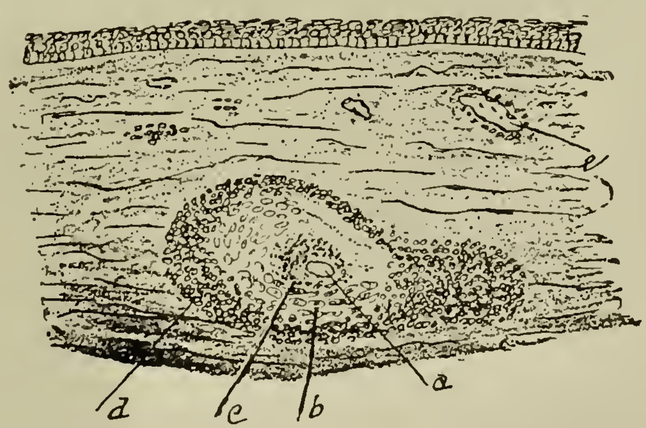
Conclusions. In the acute cases with abundant secretion, there was probably a secondary infection, combined with the diplo-bacillary conjunctivitis. The prophylactic measures taken in the 25th Regiment of Infantry were as follows:—

1. The patients were sent immediately to the hospital.
2. All soldiers who showed a hyperemic conjunctiva were isolated and put under observation in a special room in the Infirmary.
3. The clothes and bedding of the patients were baked.
4. The 3rd Battalion, which was the most infected, left their barracks, which were cleaned down and white-washed before re-occupation.
5. Measures were taken to prevent the soldiers from mixing with the contaminated civil population.—(C. P. S.) See, also, **Conjunctivitis, Sub-acute catarrhal.**

Conjunctivitis, Natatorium. See **Conjunctivitis, Swimming-pool.**

Conjunctivitis neonatorum. See **Conjunctivitis, Purulent.**

Conjunctivitis nodosa. (L.) OPHTHALMIA NODOSA. CONJUNCTIVITIS FROM CATERPILLAR-HAIRS. This form of conjunctivitis, due to the



Ophthalmia Nodosa (modified from Hanke):

a, Cross section of hair; b, c, cells resembling giant cells; d, small, round cells; e, section of blood-vessel.

entrance of caterpillar-hairs into the conjunctiva or cornea and iris, is characterized by intense pain and the appearance of nodules in the tissues involved. Lachrymation and photophobia are present. Some weeks or months after the receipt of the injury violent inflammatory symptoms supervene, and iritis and iridocyclitis are frequent complications. When nodules are found in the iris the disease may simulate tuberculosis. Often careful and repeated examinations are necessary before the hairs can be found because of their semi-transparency and light color. Excision of the nodules and the continued use of a mydriatic are called for. See, also, **Conjunctiva, Tumors of the.**

Conjunctivitis, Non-gonococcal purulent. See **Conjunctivitis, Purulent.**

Conjunctivitis palpebrarum. (L.) Palpebral conjunctivitis.

Conjunctivitis, Parinaud's. Lymphoma of the conjunctiva. It is now about twenty-five years since Parinaud first described the peculiar form of conjunctivitis which is now always known by his name, and whose origin he attributed to some infection from the lower animals. As knowledge of the disease has increased it has become more difficult to maintain the theory of its causation first advanced by Parinaud. The gross pathology is very characteristic: Swelling of the eye-lids; muco-purulent discharge; swelling of the preauricular gland and afterwards the submaxillary, parotid, and cervical; large polypoid granulations springing from the palpebral conjunctiva completing the group. The cornea has been involved on but two occasions that have been recorded (Keiper, *Ophthalmic Record,* Jan., 1911).

Verhoeff (*Arch. Ophth.,* July, 1913, XLII, 345), describes a filamentous organism which he has found to be present in cases of Parinaud's conjunctivitis and which he believes to be the cause of the disease. He has examined, histologically, twelve cases of Parinaud's conjunctivitis. All the cases presented characteristic histological lesions and within areas of cell necrosis characteristic micro-organisms were discovered. The micro-organisms were found in irregular masses, from 10 to 60 $\mu\mu$ in diameter, and were composed of filaments. The individual filament is extremely delicate, stains faintly, and has single contours. At intervals along the filament, round dots occur which stain intensely by the modified Gram method. The filaments are usually about the thickness of the influenza bacillus. With the exception of one case the micro-organisms were found only in or within the close vicinity of well-marked areas of cell necrosis.

Verhoeff summarizes as follows: "In eleven out of twelve consecutive cases, each having the clinical features described by Parinaud, and each presenting essentially the same characteristic picture,

a minute filamentous micro-organism was found. The absence of any other demonstrable micro-organisms in the lesions, the unusual character of the micro-organisms found, their great abundance, and the fact that they were so situated as to explain the lesions, leave no reasonable doubt that they were the cause of the disease. Their occurrence in the areas of cell necrosis previously pointed out by me confirms the diagnostic importance of these areas.

"Since no branching of the filaments could be made out, the micro-organism may for the present be classed as a leptothrix. So far as I can ascertain, no similar micro-organism pathogenic for man has previously been described. Now that its morphology in the tissues and suitable methods for staining it are known, its cultivation on artificial media should soon be accomplished. The experimental production of the disease should also be attempted, monkeys preferably being selected for the purpose."

For the more complete description of this disease in its clinical aspects, the reader is referred to **Parinaud's conjunctivitis,** in this *Encyclopedia.*—(C. P. S.)

Conjunctivitis, Periodic plastic. See **Conjunctivitis, Vernal.**

Conjunctivitis petrificans. Calcareous conjunctivitis. Uratic conjunctivitis. Lithiasis of the conjunctiva. Leber, in 1893, described a case of this rare disease, which is characterized by the presence in the conjunctiva of an inflammatory swelling, in which opaque white spots are to be seen. These spots consist of lime in organic, crystallizable combination; they increase in size, as the disease spreads spasmodically, and finally coalesce, forming a mass as hard as stone. New foci will appear while others are healing, and the process will thus last for months or years. The smaller foci vanish by absorption, while the larger ones leave shriveled thickened spots in the conjunctiva. Blindness may be caused by corneal involvement. The treatment consists in excising the foci when it is possible to do so.

Sidler-Huguenin, Zürich (*Arch. f. Aug.*, 73, p. 167), reports in great detail the clinical history of an hysterical girl, aged 16, otherwise healthy and of good family, who with the greatest cunning in preventing detection, produced in her eyes an artificial conjunctivitis petrificans. She semed to relish pain by introducing different kinds of lime into the conjunctival sac, grinding them with the lid, by scarifications of the conjunctiva with a needle, and contusions of the lids with subsequent sugillations. If one compares this case clinically, chemically and anatomo-pathologically with the few typical cases of conjunctivitis petrificans published (eight in all), one must concede that the true and the artificially produced conjunctivitis petrificans may present identical results.

A. Del Monte (*Archivio di Ottalmologia* XVI, 2, 3, 4, 5, 1908), gives in great detail the history of a case of this extremely rare condition, and from a most careful study of it concludes that the lesion was due to the bacillus xerosis.

The patient was a young woman of 25, a native of Naples, in perfect health so far as a very thorough examination could discover: she had no family history pointing to any morbid condition.

Del Monte gathers up the description of the case in this fashion, after having at extreme length, detailed the particulars: In an eye, hitherto sound, hyperemia of the tarsal conjunctiva and of the fornices suddenly came on and remained there about four days, accompanied by very copious secretion. Then on the middle portion of the tarsal conjunctiva below, and in the lower and lower inner sectors of the conjunctiva of the globe, there occurred hemorrhages, sometimes relatively large and single, at other times minute and multiple, these being accompanied by sharp pain and profuse lachrymation. The epithelium over these hemorrhages was shed as grayish-white detritus, the aspect of the parts resembling that of a burn of the membrane, the margins clean cut, but the floor irregular, presently covered by a whitish or yellowish membrane not easily removed even with scraping. The whole aspect of the exudate, tough, membranous, smooth, not elevated, and surrounded by a considerable zone of hyperemia, as well as of the resulting scars, suggested strongly the appearance of a diphtheritic ulcer. Other little foci appeared also, without being preceded by hemorrhages, similar in appearance, always small in size, whitish in color. The healing of these superficial ulcerations and then the return of pain, hemorrhages, and formation of fresh lesions went on for a long time, as above narrated. Apart from injection of serum no treatment seemed to produce any effect whatever.

Two morsels removed at an early stage in the morbid process were hardened, cut in series and stained with hematoxylin, eosin or carmine. It became plain from the examination of these that the morbid process divided itself into two different stages. The part removed at a very early stage in the disease showed loss of epithelium, though the surface was for the most part smooth; there were few lamellæ on the surface parallel to it, those present being homogeneous or finely granular. In the interstices of this tissue were numerous round or elongated cells, especially near the surface. In the substance the lymph spaces were very large, so much so that at parts the tissue was almost reduced to a mere large-meshed network. The vessels contained in this tissue were much dilated and showed here and there edema of the endothelium, and indeed of all the coats. In the vessels were

to be seen some leucocytes many times larger than the red corpuscles, having one or more nuclei. In the part removed at a later stage there were signs of a copious serous and cellular exudation which had taken place in the interior of a fibrous tissue.

The affected portions may be considered to consist of three layers, the first an irregular open network of wide meshes, formed of altered connective tissue, in the openings of which lie granular particles and pale, red-blood corpuscles, and over it the epithelium has been completely shed, but may be seen also beginning to form again and spread in. Immediately below this layer comes one densely infiltrated with small round cells, some with one, some with many nuclei. The connective tissue fibres here seem for the most part vertical to the surface (herein differing from those in the superficial layer) and the network has a closer mesh. The endothelium of the scanty vessels is swollen and in places detached. The deepest of the three layers is composed of young fibrous tissue, the bundles meeting and crossing at all angles and in all directions, and between these lie many large leucocytes. This brief description is amplified in the original publication by a long and particular account of a great series of sections, most carefully examined and accurately described as to actual appearance and chemical reactions.

Del Monte's impression of the course of events, as constructed by him out of the varied aspect of the sections examined with great care and in large numbers, is that an edema and cellular infiltration was the first step in the morbid process, this occurring in the more superficial layers particularly. Following upon this, by the absorption of the fluid and in consequence of the pressure undergone, which would of course be accentuated by the existence of highly resisting fibres, calcification might easily take place with the partial necrosis of tissue.

Micro-organisms were obtained in small quantities from the general surface of the ulcers, and from the vacuoles in the sub-epithelial tissue and in the broken down tissue, but in larger numbers in the surrounding zone of cellular infiltration. The diphtheritic form was most frequent, some being straight, some gently curved, with a clear central space, isolated or in small groups: less frequent were cocci solitary or in pairs; more rare short chains of 3 to 5, or bunches of 7 or 8; here and there bacillary forms in groups showing all gradations from the true diphtherial bacilli to that of cocci. There were also small bundles of ramified filaments breaking up in fragments similar to certain bacilli. Occasionally under the epithelium at the edge of the ulcers would be found large cells containing numerous bacilli,

such as are seen in xerosis; these were more frequent in the second layer of the tissue of one of the patches as described above.

Now, the xerosis bacillus is a very frequent inhabitant of the conjunctival sac both in health and disease, but always remains, says Del Monte, exterior to the epithelium. It is not described as penetrating into the tissues—yet here we find it in the tissues themselves, sometimes even in leucocytes, and in great numbers in the epithelial cells. Two forms of organism were frequently present, one bacillary, the other coccal, but not, the author was satisfied from its culture and reactions, staphylococcal; he was unable to identify it with any measure of certainty. Of the identity of the former with the xerosis bacillus, which was constantly present in the conjunctival sac of the patient, he entertained no doubt whatever.

Experiments with the organism isolated were then conducted, introducing a culture into a "pocket" in the cornea of the rabbit and observing with care the reaction produced. There was set up ulceration involving the epithelium of the cornea alone, the margins being infiltrated in all directions except along the track of the knife; further, there was slight edema and cellular (mono- and poly-nuclear) infiltration in the corneal substance over a somewhat smaller area; not unnaturally there was not evident any tendency to recurrence; it is hardly to be expected that all the characters should be reproduced, but those which were tended to encourage Del Monte in his view of the causation.

Del Monte arranges his chief conclusions on the case under six headings, thus: 1. The morbid process in the original patient was certainly parasitic in origin, as is shown by its transmission by contact and by the favorable influence of the serum. 2. In the affected tissues there was found in moderate numbers a bacillus agreeing in its characters with the bacillus xerosis. 3. This organism, an almost constant inhabitant of the normal conjunctival sac, is in other conditions never found to have penetrated the epithelium, but always is situated superficially. 4. On examination of the material removed by scraping from the ulcerated region (with due precautions against error) an organism was constantly found which was identified with all accuracy possible with the bacillus xerosis. 5. When introduced into the cornea of a rabbit in pure culture the organism thus isolated, which was evidently not merely a casual visitant but was in a condition of exceptional activity, produced a lesion of serious moment. 6. The lesion of the cornea thus induced was not similar at all to such as are produced by other organisms under similar experimental conditions, but agreed in its main features on the other hand with that which existed in the original patient.

Taking it for granted for the meantime that the disease is due to the xerosis bacillus one is faced with the great difficulty of accounting in any way for the extreme rarity of the disease in view of the well nigh constant presence of that organism in the conjunctiva; obviously more than its mere penetration into the tissue is required to explain its pathogenic activity. The success attending the use of Behring's serum in this case is curious also. Unless it were merely by virtue of polyvalence, can it be explained on the basis of the morphological and other affinities between the xerosis bacillus and the Klebs-Loeffler. The alternating periods of quiescence and activity form a singular clinical feature, the explanation of which is likewise attended with difficulty. The author inclines to Leber's suggestion in regard to a similar case that the xerosis bacillus is a variety of streptothrix which has its own life cycle to pass through, and therefore may well have periods of inactivity and of virulence.

In the *Ophthalmic Review* for January, 1896 (XV, 9), and for March, 1901 (XX, 67), will be found reviews of papers by Leber (Report of Heidelberg Congress, 1895, and v. Graefe's *Archiv.,* 1900) on this very rare and curious form of degeneration of the conjunctiva, with accounts of three or four cases. Examples have also been published by Rief, Mayweg, and Posey. A notable feature of Leber's cases is that exactly the same portion of conjunctiva, namely that of the lower inner portion, was chiefly affected, just as in Del Monte's case, and that symblepharon resulted. The description too of the white patches and of the recurring fresh attacks reads very similarly: in Leber's cases the xerosis bacillus does not seem to have been suspected as the cause.

The first case of which any record is preserved was noticed in the year 1669; the patient was believed to have been bewitched!—(C. P. S.)

Conjunctivitis phlyctenulosa. (L.) Phlyctenular conjunctivitis.

Conjunctivitis phlyctenulosa maligna. (L.) A form of phlyctenular conjunctivitis in which the vesicles are distinctly larger than in the simple form of the disease, and involve the cornea from the start. All of the subjective and objective symptoms are more marked, and there is an abundant secretion of muco-pus, and even of flocculent membrane. The vesicles are really pustules.

Conjunctivitis phlyctenulosa miliaris. (L.) A form of phlyctenular conjunctivitis in which the vesicles are multiple and very small, like little sandy prominences, extending all round the corneal margin, and even upon the cornea itself. The subjective sensations are the same as in the simple form, though they may be marked, and there may be more or less blepharospasm.